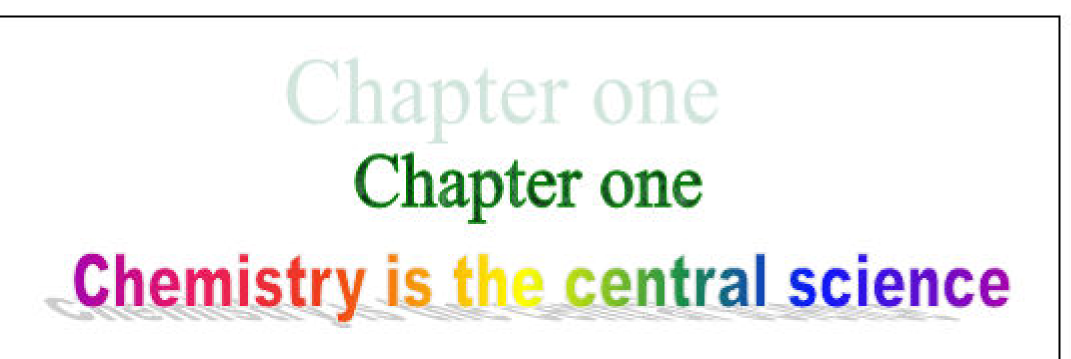


New Curriculum (2013-2014 edition)

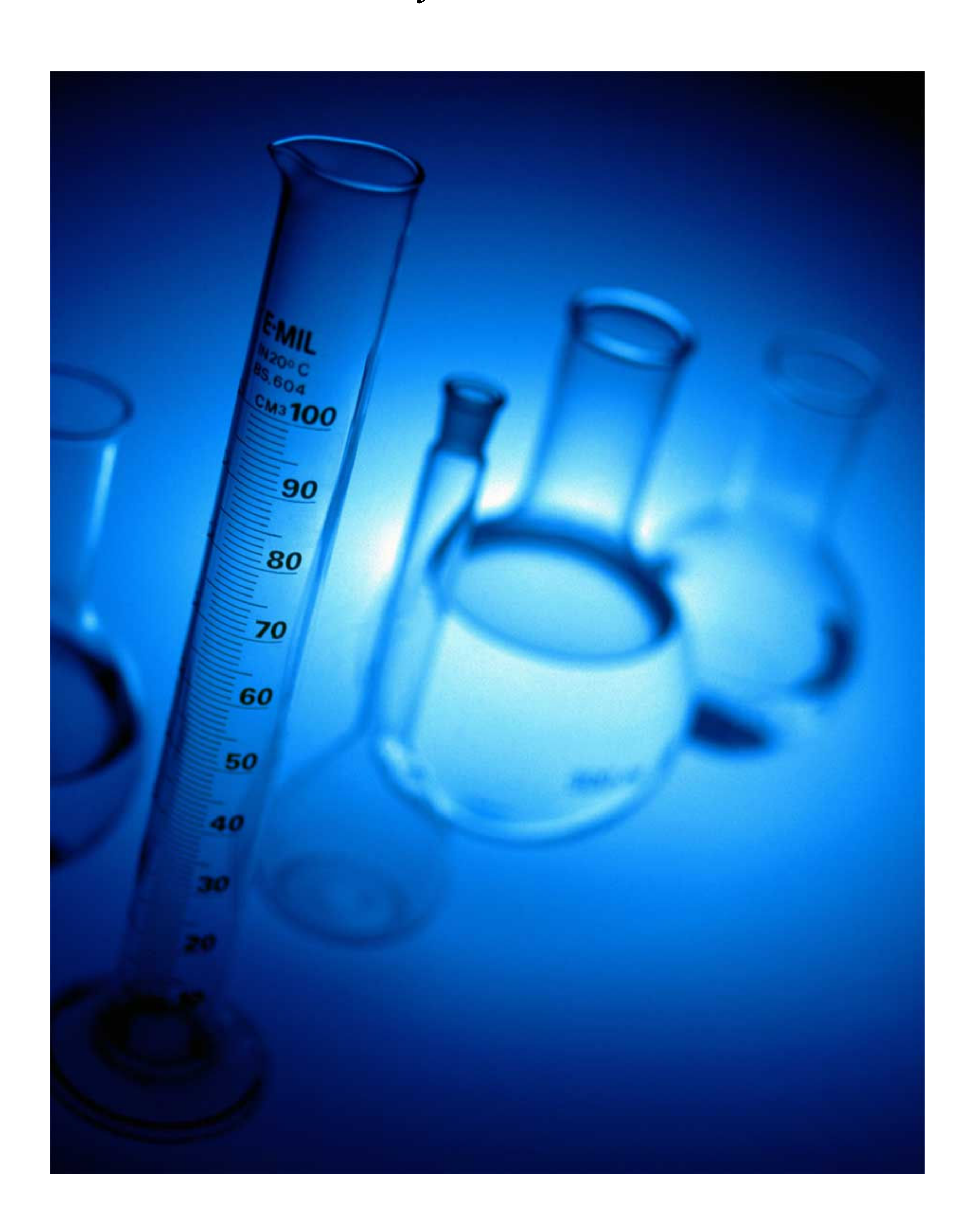
Contents



Lesson (1) Chemistry and measurement

Lesson (2) Nanotechnology and chemistry

Lesson (1)
Chemistry and measurement



Science: *The systematic building which organizes knowledge in the form of facts, principles, concepts, scientific theories and an organized way of search.*

*Each branch of science is concerned with the study of certain phenomena, one of these branches is "**Chemistry**"*

Chemistry: *The science that studies the structure and properties of matter , changes that occur to it, reaction of substances with each other and the suitable conditions for it.*

Chemistry is one of the oldest physical sciences ancient civilizations had used in all fields of life (Medicine, pharmacy, glass industry, clothes dyeing…etc). Ancient Egyptians used it in Mummification process.

Fields of study in chemistry

1- The study of the atomic and molecular structures of substances and how they bond.

2- The description of the chemical properties of substances.

3- The discovery of how substances perform their roles.

4- Chemical reactions by which reactants change into products.

5- The discovery of methods to control the conditions of the reaction; in order to create new products that serve medicine, pharmacy, industry and agriculture.

6- Solving some environmental problems (water pollution, soil pollution, air pollution, lack of water and energy resources…etc)

Chemistry is the central science

Chemistry and Biology:-

Biology: *The science that studies living organisms*

→ *Chemistry helps in understanding the chemical reactions occurring within living organisms*

Biochemistry: *The science that studies the chemical structure of of cells of different living organisms. Lipids, carbohydrates, nucleic acids and proteins are the major substances forming living organisms*

Chemistry and Physics

Physics: *The science that studies nature, matter, energy and forces.*

→ *Chemistry helps in creating new accurate measurement methods.*

Physical Chemistry: *The science that studies the structure of substances, their properties and the particles forming them.*

Chemistry, Medicine and Pharmacy

Chemistry helps in:-
1- The industry of medicines
2- understanding how hormones and enzymes work inside human body.

→ *Medicines are used to treat any disorders in them. Chemists prepare these medicines using natural substances.*

Chemistry and Agriculture

Chemistry helps in:-

1- Choosing suitable soil for planting certain crops by means of ***chemical analysis*** *which determines the ratios of soil components to know if they can satisfy the plant's needs*

2- Determination of suitable fertilizers for soil to increase its production.

3- The industry of insecticides and pesticides.

Chemistry and the future

Chemistry help us discover and create new useful extraordinary substances (by means of nanotechnology) in all fields of life (Medicine, Communications, Engineering…etc)

Branches of chemistry

1- Physical chemistry
2- Nuclear chemistry
3- Biochemistry
4- Electrochemistry
5- Environmental chemistry
6- Organic chemistry
7- Thermochemistry
8- Analytical chemistry

Measurement in chemistry

The nature of measurement

The scientific and industrial development these days are due to the right and accurate use of measurement principles

---

Measurement: *Comparing an unknown quantity to another one of the same kind to know* ***its size, degree or amount***

Measurement process should have 3 main points:-

1- Numerical value: *By which we describe the measured quantity*

2- Suitable measuring unit: *A magnitude of a certain physical quantity approved by a law and used as a standard to measure the actual magnitude of this physical quantity.*

3- Certain error ratio: *due to an error in the used device, its use conditions, or an error caused by the user.*

The importance of measurement

1- Used to know the kind and concentration of the substances we use.
2- It's essential for protection and control.
3- The evaluation of situations and proposing solutions for expected errors.

Measurement system and its units

After the industrial development during the industrial revolution (in Europe), the traditional measuring units became insufficient for measurement; which highlighted the need of unifying measurement system internationally

Old measurement systems: *the* ***French system****, then the* ***English system****, and finally* ***the international system of measuring units (IS)****(used till now)*

Measured quantity	***Unit***	***Symbol***
Length or distance	*Meter*	*m*
Mass	*Kilogram*	*kg*
Time	*Second*	*s*
Temperature	*Kelvin*	*K*
Intensity	*Ampere*	*A*
Quantity of matter	*Mole*	*Mol.*
Luminosity	*Candela*	*Cd*
Quantity of electricity	*Coulomb*	*Coul.*

**Joule (J)* $kg.m^2.S^{-2}$ *: used for measuring the amount of heat, work and energy*
*** Degree Celsius* (°C) : *used for measuring temperature (0 C = 273 Kelvin)*

Measurement tool s in chemical labs

Requirements of a chemical laboratory

1- Suitable security precautions
2- Water and heat sources
3- Places for keeping chemical substances, tools and devices

The sensitive balance:-

***Importance:** Measurement of the masses of substances*
***Most common types**: Digital balances*
***Most used types:** Top loading balances*



Fig. (1) Sensitive balance

Burette

***Description:** A long glass tube with two openings, the 1st opening is for filling the burette with the solution, while the 2nd one is fastened by a valve to control the amount of solution taken form the burette. Burette is fixed on a metallic base to keep it perpendicular. Zero point of graduation is on the top of it*

***Importance:** used in experiments that require high accuracy, such as adding small amounts of liquid during "**titration process**"*

Titration Process (for reading only): determination of the concentration of an identified analyte (component)

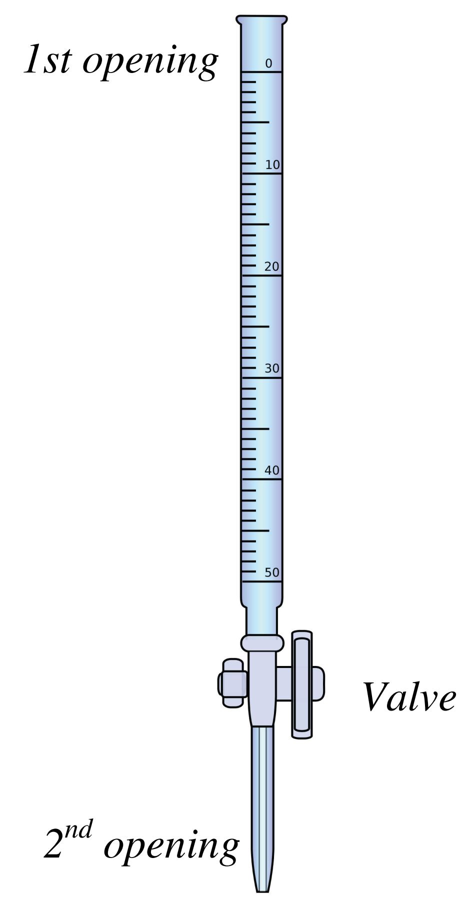


Fig. (2) Burette

Beakers

Description: *Glass containers made of* ***"Pyrex Glass"*** *that exist with different volume capacities , some of them may be graduated.*

Importance: *Holding and transporting liquids, preserving solutions during reactions and measuring their volumes.*

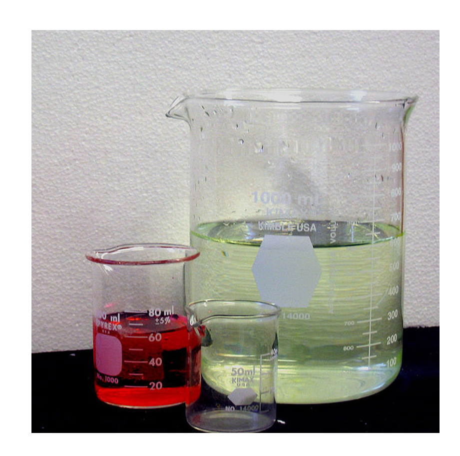


Fig. (3) Beakers of different volumes

Graduated cylinder

Description: *cylinder made of either glass or plastic, it exists with different volume capacities.*

Importance: *Holding liquids, transporting solutions and measuring the volumes of solids and solutions*



Fig. (4) Graduated cylinders of different volumes

Flasks

Description: *One of the glass tools in chemical labs*

Importance: *Preparing substances, preserving solutions and measuring their volumes (if the flask has graduation marks)*

Types:-

Conical Flasks: *made of "**Pyrex glass**" and used in "**titration process**"*



Fig. (5) Conical flask

Round- bottom flasks: *usually made of* ***"Pyrex glass"*** *and used in* ***"distillation And preparation processes"***



Fig. (6) graduated round-bottom flask

Distillation process (for reading only): *It is the purification of liquids by heating them so that they vaporize, then cooling and condensing the vapor and collecting the resultant liquid.*

Volumetric flask: *made of* ***"Pyrex glass"****, on its top there's a mark determining its volume capacity, It's used in the preparation of solutions with certain concentrations accurately.*



Fig. (7) Volumetric flasks

Pipette:-

Description: *A long glass tube with both ends open and a mark on its top determining its capacity. Measurement error ratio is written on its top. liquid sucks into it when we press the bulb above it.*

Importance: *Transport of solutions and measurement of their volumes.*



Fig. (8) Volumetric pipettes

Power of Hydrogen (pH) measurement

Definition: *pH is the measurement of the concentration of positive Hydrogen ions (H+) in the solution to know if it's an acid, a base, or neutral.*

Importance: *It plays an important role in chemical and biochemical reactions.*

pH tools:-

Litmus paper:

*We immerse a litmus paper in the solution we want to calculate its pH , so the colour of the paper changes. Then, we compare that colour to a **calibrator (ranging from 0 to 14**) in order to calculate its pH.*

Digital device (pH meter):-

→ *We immerse pH meter pole in the solution. Then the pH appears on the digital screen of the meter (pH ranges from 0 to 14)*

→ *After calculating the pH of the solution by using either litmus papers of pH meters, we compare it to the numbers of the following table.*

→ *If pH is smaller than 7 (pH<7), the solution is acidic*
→ *If pH is greater than 7 (pH<7), the solution is basic (alkaline)*
→ *If pH equals 7 (pH=7), the solution is neutral*

Definitions of lesson (1)

Science: *A systematic building that organizes knowledge in the form of facts, principles, concepts, scientific theories and an organized way of search*

Chemistry: *The science that studies the structure of matter, its properties, the changes that occur to it, the reaction of substances with each other and the suitable conditions for it.*

Biochemistry: *The science that studies the chemical structure of different living organisms, and the reactions occurring within them.*

Physical chemistry: *The science that studies the structure of substances, their properties and the particles forming them.*

Measurement: *Comparing an unknown quantity to another one of the same kind to know its size, degree or amount.*

Measuring unit: *The magnitude of a physical quantity which is approved by a law and used as a standard to measure the actual magnitude of this physical quantity*

Burette: *A long glass tube with 2 openings used to add liquids in very accurate experiments (especially in titration process).*

Beaker: *A glass container made of Pyrex glass used to hold and transport liquids, and measuring their volumes.*

Glass cylinder: *A cylinder made of either plastic or glass used to hold and transport solutions, and measuring the volumes of solutions and irregular solids.*

Round-bottom flask: *A glass tool made usually of Pyrex glass and used in distillation and preparation processes*

Volumetric flask: *A glass tool made of Pyrex glass and used to prepare solutions of certain concentrations accurately.*

Pipette: *A long glass tool with both ends open used to transport liquids (especially dangerous ones) and measure their volume.*

Power of hydrogen: *The measurement of the concentration of positive hydrogen atoms in solutions to know if it's alkaline, acidic or neutral.*

pH meter: *A digital device used for calculating the pH of solution*

Give reasons for (Rationalize)

1- The importance of chemistry

Because it studies the structure and properties of matter, changes that occur to it, reaction of substances with each other and the suitable conditions for it

2- Chemistry plays an important role in the physics

Because it helps physicists discover new accurate measurement methods. Moreover, physical chemistry (one of chemistry branches) studies the properties and structures of substances, and the particles forming them.

3- Chemistry plays an important role in biology

Because chemistry describes the chemical reactions occurring inside living organisms. Moreover, biochemistry (one of chemistry branches) studies the structure of different living organisms.

4- Chemistry plays an important role in the medicine and pharmacy

Because chemistry finds out how enzymes and hormones work inside human body, it also helps us in the manufacture of medicines.

5- Chemistry plays an important role in agriculture

Because it helps us choose suitable soil for certain crops, determine suitable fertilizers for them and helps us in the industry of pesticides

6- The rise of the idea of forming new measurement systems

Due to the industrial development after the industrial revolution in Europe, which made the old traditional measuring units insufficient for measurement

7- The occurrence of errors during measuring process (measuring process is not 100% accurate)

Due to errors in the used device, it use conditions, or error in human reading

8- The importance of measurement in chemistry

Because it's essential for protection, it helps us know the kind and concentration of the substances we need, and it also helps us evaluate situations and finding solutions for expected errors

9- The development of science and industry these days

Due to the right and accurate use of measurement principles

10- The importance of burettes in chemical laboratories

Because they are used in experiments that require high accuracy (used for adding small amounts of solutions during titration process)

11- The importance of beakers in chemical laboratories

Because they are used for holding and heating liquids, measuring their volumes and preparing chemical substances

12- The importance of glass cylinders

Because they are used for holding liquids, transporting them and measuring the volumes of solids and liquids.

13- The importance of conical flasks

Because they are used in titration process

14- The importance of round-bottom flasks

Because they are used in distillation and preparation processes

15- The importance of volumetric flasks

Because they are used for preparing solutions with certain concentrations accurately

16- The importance of pipettes

Because they are used for transporting certain volumes of solutions and measuring their volumes

17- The importance of pH (Power of hydrogen) measurement (or meter) in chemical and biochemical reactions.

Because it determines the concentration of positive hydrogen ions ($H+$) in solutions , which helps us know if they are alkaline, acidic or neutral

Questions

1- Choose the correct answer

1- Joule is used for measuring the amount of energy, heat and temperature. It equals:-

A- Kg.m2.s   B- Kg.m2.s-2   C- Kg2.m.s-1   D- Kg.m.s

2- The glass tool used for distillation and preparation processes is:-

A- round-bottom flask B- Graduated cylinder C- Pipette D- Burette

3- 0 degree Celsius (0 C) equals:-

A- 235 Kelvin   B- 273 Kelvin   C- 365 Kelvin   D- 154 Kelvin

4- The measuring unit of matter quantity is:-

A- Candela   B- Mole   C- Kilogram   D- Ampere

5-………. Studies the chemical structure of living organisms

A- Biochemistry   B- Physical chemistry   C- Electrochemistry   D- Analytical chemistry

6- The small volumes of liquids can be measured by:-

A- Graduated beaker   B- Volumetric flask C- Graduated cylinder D- Test tube

2- Rationalize

1- The importance of measurement in chemistry

2- Chemistry is regarded as the centre of sciences as biology and physics

3- pH measurement is important for chemical and biochemical reactions

3- Write the scientific term

1- The systematic building that organizes knowledge in the form of facts, principles, concepts, scientific theories and an organized way of search

2- The science that studies the structure of matter, its properties and the changes that occur to it

3- Comparing an unknown quantity to another one of the same kind to know its size, degree or amount.

4- A long glass tube with both ends opened whose graduation begins at its top

5- A device used in the measurement of masses of substances

4- Mention the names of tools

Tool	**Use**
	Measuring the volumes of irregular bodies and liquids
	Transporting a certain volume of liquid
	Adding small amounts of liquids during titration process
	Preparing solutions with certain concentrations accurately

Solutions

1- Choose the correct answer

1- Kg.m2.s-2
2- round-bottom flask
3- 273 Kelvin
4- Mole
5- Biochemistry
6- Graduated cylinder

2- Rationalize

1- Because it's essential for protection, it helps us know the kind and concentration of the substances we need, and it also helps us evaluate situations and finding solutions for expected errors

2- Because chemistry describes the chemical reactions occurring inside living organisms, it helps us discover new accurate measurement methods (in physics)

3- Because it determines the concentration of positive hydrogen ions (H+) in solutions , which helps us know if they are alkaline, acidic or neutral.

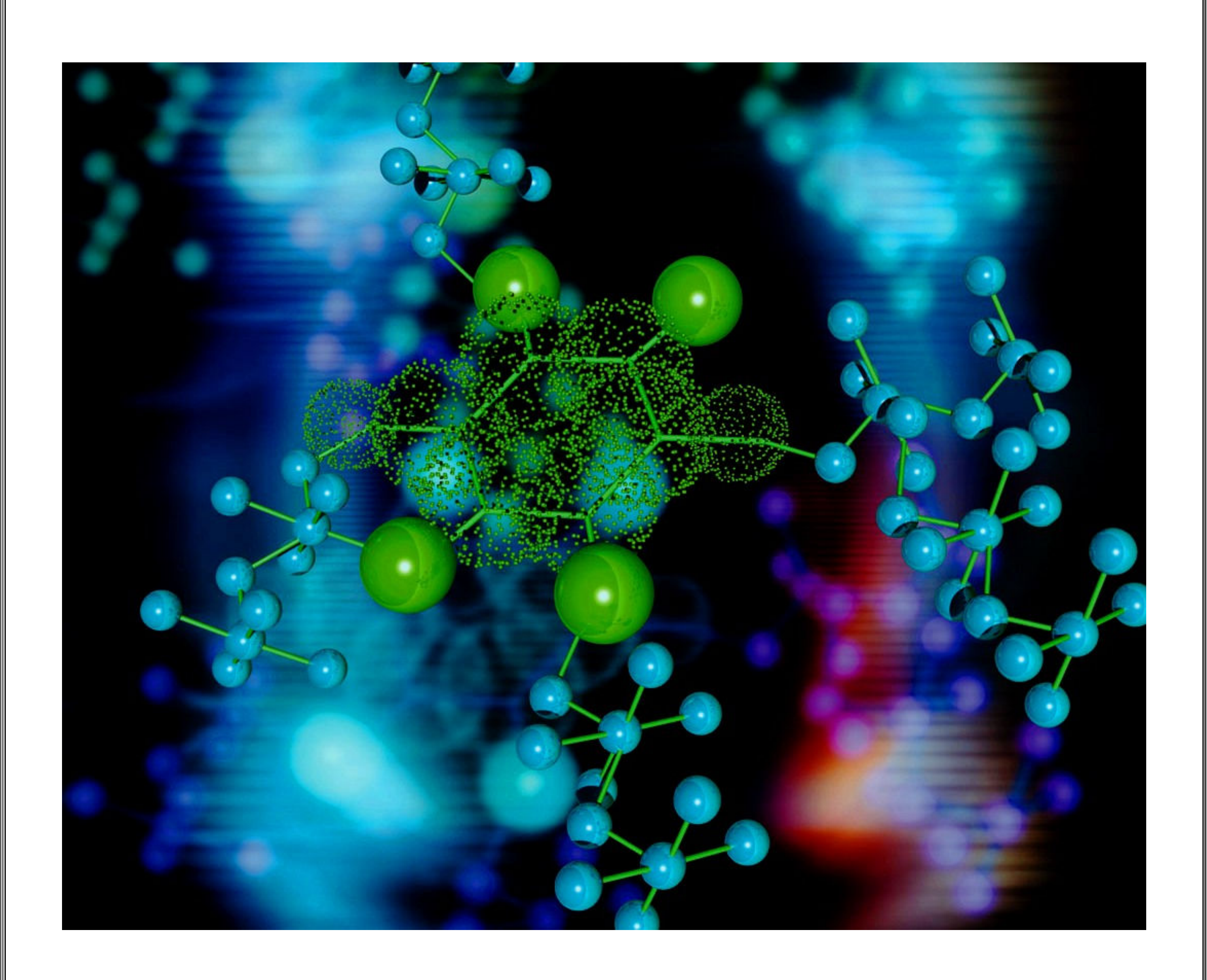
3- Write the scientific term

1- Science
2- Chemistry
3- Measurement
4- Burette
5- Sensitive balance

Write the name of tools in the following table

Tool	***Use***
Graduated cylinder	*Measuring the volumes of irregular bodies and liquids*
Beakers	*Transporting a certain volume of liquid*
Burette	*Adding small amounts of liquids during titration process*
Volumetric flask	*Preparing solutions with certain concentrations accurately*

Lesson (2)
Nanotechnology and Chemistry



Nanotechnology: *The technology of tiny objects, concerned with the manipulation of matter on Nanoscale to create new, special and useful products.*

Concept "Nanotechnology" consists of two words:-
Nano *: which is derived from the Greek word "Nanos" which means dwarf*
Technology: *The practical usage of knowledge in a certain field.*

→ *Nanometer is a special measuring unit which equals one billionth meter 0.000000001 or* 10^{-9} *meter*

Millimeter equals 0.001 or $10^{-3}\,m$
Micro meter equal 0.000001 or $10^{-6}\,m$

→ *The diameter of a sand granule equals* $10^{6}\,nm$
→ *The diameter of water molecule equals 0.3 nm*
→ *The diameter of atom ranges from 0.1 to 0.6 nm*

→ *Scientists discovered that some properties of substances (colour, solidity, flexibility, melting point, speed of chemical reaction…etc) changes on* ***Nanoscale****. Such properties are known as* ***"Size-dependant properties"*** *because they change by the change of size.*

Size-dependant properties*: properties that change by the change of matter size.*

Nanoscale: *The scale on which Nanoproperties of matter appears. It ranges from 1 to 100 nm.*

The size-dependant properties of nanoparticles

Nanogold*:-*

→ *Gold is known for its shiny yellow color, but when its size shrinks, its colour changes. Scientists discovered that Nanogold has many colours (such as green, orange and red) which differ according to the Nanosize of gold particles.*

→ *Nanogold particles are used in the treatment of caner*



Fig. (10) Different Nanogold colour

Nano copper:-

→ *The solidity of copper molecules increases when they begin shrinking from **macroscale** to **nanoscale**.*



Fig. (11) Nano copper

→ *Nanoparticles have extraordinary size-dependant properties due to the increase of the ratio between their surface areas and volumes and the no. of atoms.*

→ *When the size of a substance shrinks, the ration between surface area and volume increases (S.A increases, while volume decreases)*

Nanochemistry

***Nanochemistry**: One of Nano sciences which deals with the chemical applications of nanotechnology.*

→ *Nanochemistry is concerned with the description, study and creation of substances on nanoscale, and the unique properties of collecting atoms and molecules on nanoscale*

→ *Nanomaterials have a lots of different shapes (thin films, tubes, granules…etc), all of them range from 1 nm to 100nm, they're classified into:-*

One-dimensional Nanomaterials

Thin films

1- used for painting roofs to protect them from corrosion and rusting
2- used for packaging food products to protect them from pollution and damage



Fig. (12) Thin films

Nanowires

1- used in the manufacture of electric circuits

2- used in the manufacture of Nanofibres (which are used in the industry of water filters)

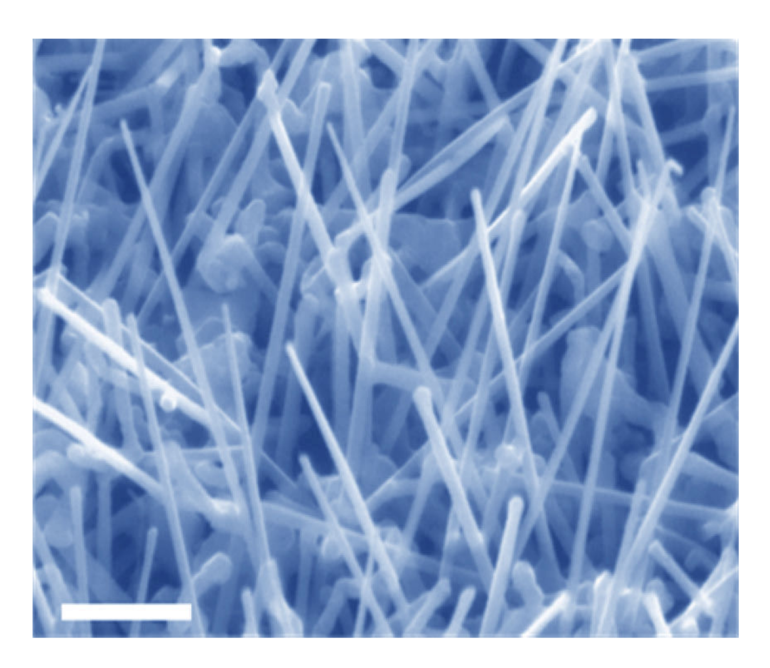
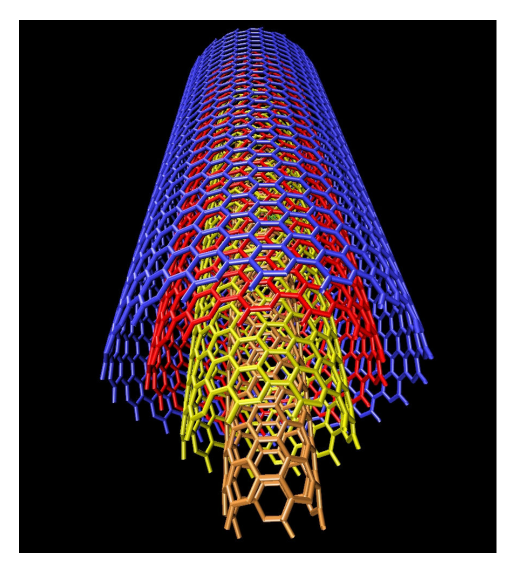


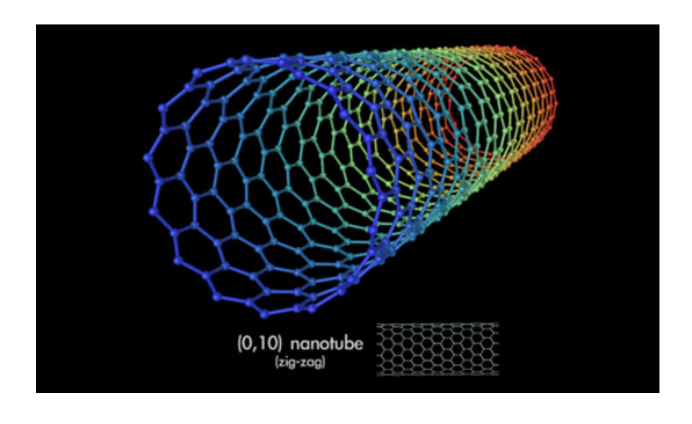
Fig. (13) Nanowires

Two-dimensional Nanomaterials

Carbon nanotubes*: single-walled or multi-walled tubes made of carbon molecules*



Multi-walled tubes



single-walled tube

Properties of carbon nanotubes:-

1- They are good conductors of heat and electricity: *They conduct electricity better than copper and conduct heat better than diamond.*

2- They are stronger than steel due to the strong bonds between their molecules: *A nanotube of the size of a hair follicle can carry a whole train!!! Which made scientists think of using it in the manufacture of ropes in space-elevators*

3- They can bond easily with proteins: *because of this property, they can be used as a biological sensors.*

Three-dimensional Nanomaterials:-

Nanoshells: *used in the treatment of cancer*

Bucky ball: *A ball made of 60 carbon atoms with the formula C60, it has a lot of properties which depend on its structure*

Importance of Bucky balls

Scientists are working on using it to carry medicines inside human body, as its hollow structure suits molecules of certain medicines, which prevent the occurrence of reactions with the medicines molecules and increases their efficiency .

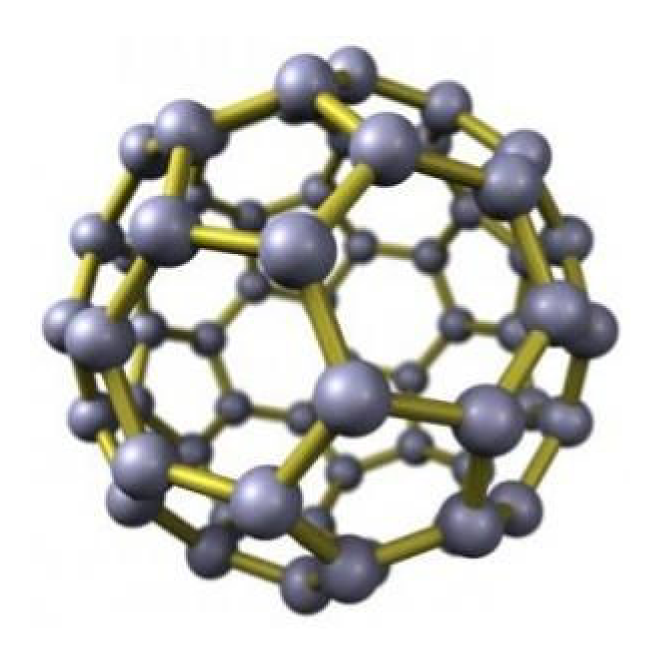


Fig. (14) The design of Bucky ball

Nanotechnology Applications

In Agriculture

1- Finding bacteria in food products.
2- Food preservation
3- Improving nutrients, insecticides and medicines for plants and animals with certain specifications

In medicine

1- Early diagnosis of diseases

2- Photographing organs and tissues

3- Transport of medicine right to the infected parts of the body; which improves its efficiency and decreases its sides effects.

4- Creation of very tiny devices for dialysis (which are being transplanted inside the patient's body)

5- Creation of tiny robots which remove blood clots from the walls of arteries in human body

In the field of energy

1- Production of solar batteries using Nano silicon (they are preferred to be used because they don't leak thermal energy and have higher ability to transform energy)
2- Production of cheap hydrogen fuel cells with higher efficiency

In industry

1- Production of unseen nanoparticles which give glass and ceramic auto-cleaning property.

2- Production of nanomaterials which purify ultraviolet rays to improve anti-sun creams and cosmetics

3- Improving packaging technology using nanomaterials in the form of sprays and paintings, which form protective layers on electronic devices to protect them from scratches.

4- Production of stain-repellent clothes with auto-cleaning property

Communication:-

1- The manufacture of Nano wireless devices, satellites and mobile phones.
2- Shrinking the size of transistors
3- The manufacture of electronic chips with high capacities.

Environment:-

The manufacture of Nano filters which work on:-

1- Purifying water and air
2- Water desalination
3- Solving the problem of nuclear wastes
4- Removing dangerous elements from industrial wastes

Adverse effects of nanotechnology

Health Effects:-

Nanoparticles can penetrate the cells of lungs and skin in human, and the cells of plants and animals; which may cause health problems to them.

Environmental effects:-

The dangerous tiny wastes resulted from nanotechnology can attach to air (due to their tiny sizes), which make them able to penetrate both plant and animal cells. They also affect climate, water, soil and air.

Social effects:-

It may worsen the problems of social and economic inequality, and the unfair distribution of technology and wealth.

Nanopollution: *The pollution resulted from the substances and wastes produced by nanotechnology*

Definitons of chapter (1)

Nanotechnology: *The technology of tiny objects, concerned with the manipulation of matter on a nanoscale to create new, special and useful products.*

Nanomaterials: *Materials whose sizes range form 1 to 100 nm which have unique size-dependent properties.*

Nanochemistry: *One of Nano sciences which deals with the chemical applications of nanotechnology*

Nanopollution: *The pollution resulted from the substances and wastes produced by nanotechnology*

Rationalize (Give reasons for)

1- The importance of Nanochemistry
Because it deals with the chemical applications of nanotechnology and the unique properties of Nanomaterials

2-The extraordinary properties of nanomaterials
Due to the increase of the ratio between the surface area and volume and the no. of atoms on the surface.

3- size-dependant properties are called by this name
Because such properties change by the change of the size of substance

4- The importance of thin films.
Because they are used for plating roofs to protect them from corrosion and rusting, and packaging food industries to protect them from damage and pollution

5- The importance of Nanowires
Because they are used in the manufacture of electric circuits and Nano fibers (which are used in water filters industry)

6- The importance of carbon nanotubes
Because they are good conductors of heat and electricity, they can be used as biological sensors (due to their sensitivity to certain substances), and they also can be used in the manufacture of ropes in space-elevators (due to their solidity)

7- The importance of Bucky balls
Because they can be used for carrying medicine inside human body (which decreases side effects)

8- Nanotechnology plays an important role in medicine
Because it helps us diagnose diseases early, photograph organs and tissues, transport medicine right to the infected parts of the body, create tiny robots that remove blood clots from the arteries walls and transplant tiny devices to perform dialysis inside patients.

9- Nanotechnology plays an important role in agriculture
Because it helps us find bacteria in food and improve insecticides and medicines for animals and plants, it also plays an important role in food preservation.

10- Nanotechnology improves energy resources
Because we can use it in the manufacture of sun batteries using Nano silicon (which are better at energy transformation and don't leak thermal energy),

and hydrogen fuel cells with cheaper price and higher efficiency

11- Nanotechnology plays an important role in industry field

Because it can be used in the creation of nanoparticles which give glass auto-cleaning ability , and the manufacture of nanomaterials which purify ultraviolet rays (which are used in anti – sun creams and cosmetics) and stain-repellant clothes that can auto-clean themselves. It's also used for forming protective layers on electronic devices

12- Nanotechnology plays an important role in communication field

Because it is used for shrinking transistors sizes, used in the manufacture of Nano wireless devices, satellites, mobile phones and electronic chips with high capacities.

13- Some nanotechnology applications serve the environment

Because it can be used in the manufacture of Nano filters which work on solving nuclear wastes problem, purifying air and water, and removing the dangerous elements from industrial wastes

14- Nanosubstances have adverse health effects

Because their tiny sizes make them able to attach to air, so they can penetrate the cells of human, animals and plants.

15- Nanotechnology has adverse environmental effects

Because the tiny wastes resulted from nanotechnology can attach to air and penetrate both animal and plant cells. It also affects climate, water, air and soil

16- Nanotechnology has negative social effects

Because it may worsen the problems of unfair distribution of wealth and technology, social and economic inequality.

Questions

1- Choose the correct answer

1- …….. are from one-dimensional nanomaterials
A- Carbon nanotubes B- Thin films C- Bucky balls D- Nanoshells

2- One nanometer equals…. Meter
A- 10-7 B- 10-9 C- 10-6 D 10-4

3- nanotechnology is important because:-
A- It needs special devices to deal with it
B- Its value ranges from 1 to 100 nm
C- It has special properties
D- Nanomaterials industry require special properties

4- The small volumes of liquids can be measured by:-
A- Graduated beaker B- Volumetric flask C- Graduated cylinder D- Test tube

5- Which one of the following numbers is the greatest
A- 10^-3 B- 10^-2 C- 10^-7 D- 10^-9

6- When dividing a cube into smaller cubes
A- The surface area decreases while the volume increases
B- The surface area increases while the volume decreases
C- The surface area doesn't change while the volume increases
D- Both surface area and volume don't change

7- The behavior of nanoparticles are linked with their tiny sizes because:-
A- The ratio between surface area and volume is very great if compared to bigger sizes
B- The ratio between surface area and volume is smaller if compared to smaller sizes
C- The no. of atoms on the particles surface is much greater
D- A and C

2- Write the scientific term

1- It's concerned with the manipulation of matter on a nanoscale
2- A Nano science which deals with the chemical applications of nanotechnology
3- Used for measuring the volumes of irregular solids and liquids
4- It's concerned with the study, creation and description of nanomaterials
5- A unit which equals one billionth meter

6- Substances whose sizes range from 1 to 100 nm

3- Compare between

1- Copper solidity and nanocopper
2- normal sun batteries and Nano sun batteries

4- Write short notes about

1- The positive and negative health effects of nanotechnology
2- The importance of the ratio between surface area and volume in nanoparticles

5- What is meant by

1- Measurement
2- Measuring unit
3- Nanotechnology

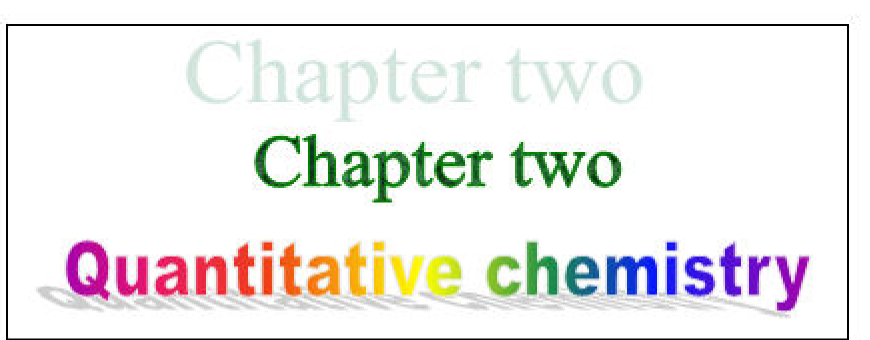


1- Choose the correct answer

1- Thin films
2-10-9
3- It has special properties
4- Graduated cylinder
5-10^-2
6- The surface area increases while the volume decreases
7- The ratio between surface area and volume is smaller if compared to smaller sizes

2- Write the scientific term

1- Nanotechnology
2- Nanochemistry
3- Graduated cylinder
4- Nanochemistry
5- Nanometer
6- Nanomaterials



Lesson (1) Mole and chemical equation
Lesson (2) Calculating chemical formula

Lesson (1)
Mole and chemical equation



Chemical equation

→ *When oxygen gas reacts with magnesium, magnesium oxide is formed. Such Reactions are described by balanced equations known as "**chemical equations**"*

$$2Mg_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2MgO_{(s)}$$

Chemical equation properties

1- It is composed of the chemical formulas and symbols of the reactants and products

*2- Both sides of the equation (the reactants and products) are separated by an arrow describing the conditions and direction of the reaction **(in the previous equation, the triangle on the arrow describes heat)***

3- It describes the quantity of reactants and products (the no. of molecules)

*4- It describes the state of reactants and products – **solids are denoted by (s), liquids (l), gas (g) and aqueous solutions (aq.)** as shown in the previous equation*

→*Chemical equations should be balanced, which means that the no. of molecules of reactants should equal the no. of molecules of products. This is known as **"law of mass conservation"***

***Chemical equation:** The representation of chemical reaction using chemical symbols, formulas of reactants and products, and the description conditions of reaction.*

***Molecule:** is the smallest particle in a chemical element or compound that has the chemical properties of that element or compound and exists alone*

***Atom:** The smallest building unit of matter which takes part in chemical reaction*

How to balance a chemical equation:-

→ *to balance a chemical equation, we should make sure that the right side of the equation has the same atoms of the left side of it.*

Example (1)

Balance the following equations:-

1- $Al + O_2 \rightarrow Al_2O_3$

2- $NaNO_3 \xrightarrow{\Delta} NaNO_2 + O_2$

Solution:-

*1- we find that there are 3 oxygen atoms on the right side of the equation, while there are only 2 on the left side of it. To balance the no. of oxygen atoms on both sides, we should increase the no. of oxygen atoms on both of them to 6 (**6 is the least common multiple of 2 and 3**)*

$$Al + 3\ O_2 \rightarrow 2\ Al_2O_3$$

There are four aluminium atoms on the right side of the equation, while there's a single atom on the left side. To balance the no. of aluminium atoms on both sides, we increase the no. of atoms in left size to 4 aluminium atoms

$$4Al + 3\ O_2 \rightarrow 2\ Al_2O_3$$

2- The no. of oxygen atoms on the right side of the equation is 3, while that on the right side of the equation is 4, to balance the no. of oxygen atoms, we increase the no. of oxygen atoms on both sides to 6

$$NaNO_3 \ \Delta \rightarrow NaNO_2 + O_2$$

The Mole

*We studied before that every element has its own **mass number** (the number of protons and neutrons in the nucleus of the element atom)*

*Thus, if we want to calculate the atomic mass of an element , we only calculate the mass of its **nucleus (because the mass of electrons is too small if compared to those of protons and neutrons**)*

*Atomic masses are measured by a unit called **"Atomic unit"** or **a.m.u**.*

Atomic unit (a.m.u) = 1.66 x 10-24 gm = 1.66 x 10-27 kilogram

If the mass no. of oxygen is 12, so its atomic mass equals 12 a.m.u and so on.

"Mole" (the abbreviation of molecule) is the measuring unit of the quantity of matter

How to calculate the mole of elements

If the atomic mass of oxygen is 16 a.m.u, so one mole of oxygen equals 16 grams
If the atomic mass of nitrogen is 14 a.m.u, so one mole of nitrogen equals 14 grams

If the atomic mass of carbon is 12 a.m.u, so one mole of carbon equals 12 grams

*If we want to know the mass of a molecule of a compound, we add the masses of the atoms forming it, which is known as "**Molecular mass**"*

Molecular mass: *The sum of the masses of the atoms forming molecules of a compound*

Example:-

The molecular mass of carbon dioxide molecule (CO2) is the sum of the masses of 2 oxygen atoms and 1 carbon atom.

if the atomic mass of oxygen equals 16 a.m.u, and that of carbon atom equals 12 a.m.u

Therefore, the molecular mass of CO2 molecule = 12+16+16 = 44 a.m.u

→ Mole of CO_2 = 44 gm

<u>Mole and the mass of matter</u>

We calculated before that mole of carbon dioxide equals 44 gm, so when we use 44 gm of carbon , it means that we used one mole of it

<u>How to know the no. of moles in matter</u>

$$\frac{\text{The mass of matter (in grams)}}{\text{The mass of one mole (gm/mole)}}$$

*→ The no. of carbon dioxide moles in 440 grams of it equals 440 (the mass of matter) **divided by** 44 (the mass of one mole) = 10 moles*

*→ Every substance has different molar mass **due to the difference of the molecular structure and atomic masses of elements***

→ The mole of diatomic (nonmetal) elements are calculated by a different way
The mole of oxygen gas (in the form of molecules) O_2 = 16+16= 32 gm
The mole of oxygen gas (in the form of atoms) = 16 gm

→ There are some elements whose molar masses change by the change of their physical state (solid, liquid, gas) for example:-

***Phosphorus**: Phosphorus molecule in gaseous state consists of 4 Phosphorus atoms (P_4) while its molecule in solid state consists of only 1 atom*

Sulphur: Sulphur molecule in gaseous state is octatomic (consists of 8 atoms), while its molecule in solid state consists of only 1 atom

The importance of mole

It helps us calculate the amounts of substances required for chemical reaction

$$2Mg_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2MgO_{(s)}$$

From the previous reaction, we deduce that the ratio between magnesium and oxygen equals 2:1, so the reaction needs 2 magnesium moles and 1 oxygen mole (the no. of moles of magnesium should be double that of oxygen)

Limiting reactant

*→ We said that chemical reactions require certain amounts of reactants to get the required amount of products But if the amount of a certain reactant is smaller than the required amount, it's completely consumed. Such small amounts of reactants are known as **"Limiting reactant"***

***Limiting reactant:** The substance that is totally consumed when chemical reaction is complete due to its lack*

Mole and Avogadro's number

*Scientist **Amedeo Avogadro** discovered that the no. of matter units (atoms,molecules,ions…etc) in all moles of all elements is constant. Later, that no. was calculated to be **6.02×10^{23}** and called "Avogadro's number"*

***Avogadro's number:** A constant number representing the no. of atoms, molecules or ions in one mole, it equals 6.02×10^{23} matter unit/mole*

→ One mole of water (44 gram of it) has 6.02×10^{23} molecules and so on

Example (1)

Calculate the no. of carbon molecules in 48 grams of carbon (C=12)

***Solution**:-*

The mole of carbon = 12+12 = 24g (diatomic element)
Therefore, the no. of moles = 48 /24 = 2 moles
The no. of molecules = 2 x 6.02×10^{23} = 12.04×10^{23} atoms

Example (2)

Calculate the no. of carbon atoms in 50 grams of calcium carbonate $CaCO_3$ (Ca = 40, C=12, O=16)

Solution:-

One mole of $CaCO_3$ = 40 + 12 + (16x3) = 100 gm

Therefore, 100 gm (one mole) of $CaCO_3$ contains one mole of carbon

50 gm of $CaCO_3$ = 0.5 mole of $CaCO_3$ = 0.5 mole of carbon

The no. of carbon atoms = 0.5 x 6.02×10^{23} = 3.01×10^{23} atoms.

Ionic reactions

→ *Some physical processes, as the dissociation of some molecules into ions when they dissolve in water, are described by **"ionic reactions"***

→ *When dissolving sodium chloride in water, we describe it by the following ionic reaction:-*

$$NaCl_{(s)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$$

→ *The previous reaction states that a solid mole of NaCl produces a mole of positive sodium ions (6.02×10^{23} ions) and a mole of negative chlorine ions (6.02×10^{23} ions) when it dissolves in water*

When sulphuric acid reacts with sodium hydroxide forming sodium sulphate and water (Neutralization reaction) , we describe the reaction as the following:-

$$2NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$$

We can describe the previous neutralization reaction by an ionic equation:-

$$\cancel{2Na^+_{(aq)}} + OH^-_{(aq)} + H^+_{2(aq)} + \cancel{SO_4^{-2}} \rightarrow \cancel{2Na^+} + \cancel{SO_4^{-2}} + 2H_2O_{(l)}$$

→ *We will notice from the previous ionic equation that the ions of sodium and sulphate didn't take part in chemical reaction, but they form bonds with water molecules forming sodium sulphate.*

→ *Ionic equation the reactions of ions with each other forming new compounds. Therefore, ions of sodium and sulphate were omitted because they didn't react with other ions. The final ionic equation of this neutralization reaction is:-*

$$OH^-_{(aq)} + H^+_{2(aq)} \rightarrow 2H_2O_{(l)}$$

Example:-

When adding potassium chromate ($K_2C_2O_7$) to silver nitrate solution ($AgNO_3$), insoluble silver chromate($Ag_2Cr_2O_7$) is formed as a red ppt.

$$K_2Cr_2O_{7(aq)} + 2AgNO_{3(aq)} \text{---------}\rightarrow 2KNO_{3(aq)} + Ag_2Cr_2O_7$$

Find the ionic equation of the previous reaction.

Solution:-

$$2K^+ + 2Cr^+ + 7O^- + 2Ag^+ + 2NO_3^- \rightarrow 2K^+ + 2NO_3^- + K_2Cr_2O_7$$

→ *Potassium and nitrate ions are removed because potassium nitrate is an aqueous solution. Therefore, they didn't react with any other ions.*

$$2Cr^+_{(aq)} + 7O^-_{(aq)} + 2Ag^+_{(aq)} \rightarrow + K_2Cr_2O_{7(s)}$$

→ *We can use the following steps to solve any ionic equations:-*

1- We write the reactants of left hand side in the form of ions

2- Aqueous products (which have aq signs near them) on left hand side are written in the form of ions), but we don't change the other products

3- We omit the ions of aqueous solution product from both sides.

4- Finally, we write the ionic equation

Mole and volume of gases

It's known that the volume of gas is the volume of its container, but scientists discovered that moles of all gases occupy certain volume of 22.4 litres if they are put in certain conditions called "Standard temperature and pressure (STP)"

STP: *The presence of matter in temperature of 0 degree Celsius (273 Kelvin) and pressure of 760 mm.Hg (1 atomic pressure)*

→ *This means that a mole of methane gas (CH_4) occupies volume of 22.4 litres (if it's in (STP), and the same to a mole of Hydrogen gas (H_2) and any gas.*

Volume of gas (in litres) = 22.4 x no. of moles

Example (1)

Calculate the volume of 64 gm of oxygen gas in STP conditions (O=16)

Solution:-

If one mole of oxygen =16+16= 32 gm (diatomic element)

The no. of moles = 64 /32= 2 moles

The volume of oxygen gas = 22.4 x the no. of moles = 22.4 x2 =44.8L

Example:-

Calculate the volume of oxygen required for 90 g of water when reacting with hydrogen in STP (O= 16, H=1)

Solution:-

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O$$

2 mol 1 mol 2 mol

One mole of water = 16 + 1x2 = 18 grams

If one mole of oxygen produces 2 moles of water(36 grams of water)

Therefore, The no. of moles in oxygen = 90/36 = 2.5 mol

The volume of oxygen = 22.4 x2.5 = 50 L

Laws on gases and mole

Gay-Lussac's law: *The volumes of reactant and product gases have certain volumes expressed in whole numbers*

→ *In other words, The volumes of reactant gases and the products are inversely proportional, which means that:-*

1- If one volume of hydrogen reacts with one volume of chlorine, one volume of hydrogen chloride gas is formed

$$H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$$

2- If one volume of nitrogen reacts with 3 volumes of hydrogen, 2 volumes of ammonia gas are formed

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$$

Avogadro's law: *Equal volumes of gases in the same conditions of pressure and temperature have the same no. of molecules*

→ *Avogadro stated that any gas of volume 22.4L (one mole of gas) in the standard conditions of pressure and temperature (STP) has $6.02x10^{23}$ molecules*

At the end of this lesson, we conclude that mole has three definitions:-

1- The mass of molecules, ions and atoms in grams

2- A constant no. of molecules, atoms, ions or formula units whose value equals $6.02x10^{23}$

3- The mass of 22.4L in standard conditions of pressure and temperature

---

Mole: *The quantity of matter which contains Avogadro no. of ions, molecules or ions*

Definitions of lesson (1)

Chemical equation: *The representation of chemical reaction using chemical symbols,. formulas of reactants and products, and the conditions of it*

Avogadro's number: *The no. of ions, molecules and atoms in one mole of matter ($6.02x10^{23}$ matter unit/mole)*

Mole: *The mass of atoms, molecules, or formula units of matter in grams which contain Avogadro's number of them*

Avogadro's law: *Equal volumes of gases in the same conditions of pressure and temperature have the same no. of molecules*

Gay-Lussac's law: *The volumes of reactant and product gases have certain volumes expressed in whole number*

Give reasons for (Rationalize)

1- The volume of 26 gm Acetylene gas (C_2H_2) is equal to the volume of 2g of hydrogen gas in (STP) conditions

Because the mole of Acetylene molecule equals 26 gm, and the mole of hydrogen molecule equals 2g. By applying Avogadro's law, we'll find that the volumes of both gases are equal in (STP) conditions (because they contain the same no. of moles)

2- The molar mass of phosphorus differs according to its physical state

Because in gaseous state, phosphorus molecule consists of 4 atoms, while in solid state, It consists of 1 atom. So, the molar mass of gaseous phosphorus is different from that of solid phosphorus

3- Litre of oxygen gas has the same no. of molecules in a litre of chlorine gas in STP conditions

Because according to Avogadro's law, equal volumes of gases in STP conditions have the same no. of molecules

4- the no. of molecules in 9 gm of water H_2O is equal to that in 39 gm of Aromatic Benzene (C_2H_2)

Because the mass of one mole of water = 9 gm, whereas the mass of one mole of Aromatic Benzene = 39 gm, so they have the same no. of molecules (Avogadro's number) because they have the same no. of moles

5- Chemical equations should be balanced

In order to get the required amounts of products

6- Gas should be in STP conditions in order to calculate its volume using its molar mass

Because in STP conditions, one mole of any gas occupies volume of 22.4 litres

7- The molar mass of sulphur in solid state is different from that in gas state

Because a molecule of gaseous sulphur contains 8 atoms of sulphur, while that of solid sulphur contains only 1 atom. So, They have different molar masses



1- Choose the correct answer

1- When 50 gm of $CaCO_3$ decomposes thermally, ……..gm of CaO is formed (Ca = 40, C=12, O=16)

A- 28 B- 16 C- 76 D- 35

2- The volume of hydrogen required to form 11.2 L of water is……….

A- 22.4 L B- 11.2 L C- 68.2 L D- 44.8 L

3- One atomic unit equals …………. Gm

A- $1.66x10_{-24}$ B- $2.73x10_{-23}$ C- $1.75x10_{-15}$ D- $3.65x10_{-13}$

4- The unit used in IS for measuring the quantity of matter is…..

A- Mole B- Joule C- Calenda D- Kelvin

5- The mass of 44.8L of ammonia gas (NH_3) in STP conditions is ………gm. (N=14, H=1)

A- 0.5 B-2 C- 17 D- 34

6- If an amount of sodium has $3.01x10^{23}$ atoms, so its mass is ....gm
A- 11.5 B- 0.5 C- 23 D-46

7- The chemical equation should be balanced according to ....
A- Avogadro's law B- Gay-Lussac's law C- law of mass conservation
D- Law of energy conservation

8- 0.5 mole of carbon dioxide gas (CO_2) weighs..... gm (C=12, O=16)
A- 22 B- 44 C-66 D-88

9- When 64 gm of oxygen reacts with hydrogen, ... litres of water vapour (H_2O) are formed
A- 11.2 B- 22.4 C- 44.8 D- 89.6

10- The no. of moles in 36g of water equals............ (H=1,O=16)
A- 1 B-2 C- 3 D- 4

11- The no. of molecules in 128g of sulphur dioxide (SO_2) equals...... (S=32, O=16)
A- 2 B- $6.02x10^{23}$ C- $3.01x10^{23}$ D- $12.04x10^{23}$

12- The no. of sodium ions resulted from the dissolution of 40g of sodium hydroxide (NaOH) equals.....(Na=23,O=16,H=1)
A- 2 B- $6.02x10^{23}$ C- $3.01x10^{23}$ D- $12.04x10^{23}$

13- The volume of 4g of hydrogen in STP conditions equals ...
A- 11.2 B- 22.4 C- 44.8 D- 89.6

14- The volumes of reactant gases are inversely proportional to those of products according to..........
A- Avogadro's law B- Gay-Lussac's law C- law of mass conservation
D- Law of energy conservation

2- Solve the following problems

1- Find the no. of sodium ions resulted from the dissolution of 117g of sodium chloride (NaCl) in water (Na=23,Cl=35.5)

2- 26.5g of sodium carbonate (Na_2CO_3) reacted with an abundant amount of hydrochloric acid in STP conditions (Na=23,C=12, O=16) find:-

a- The no. of water molecules
b- The volume of carbon dioxide gas

3- Calculate the no. of moles in 144gm. of carbon (C=12)

4- Calculate the mass of 2.4 moles of calcium carbonate ($CaCO_3$)
(Ca=40, C=12, O=16)

5- Calculate the volume of 56g of nitrogen gas in STP conditions (N=14)

6- 23g of sodium (Na) reacted with water(H_2O) forming sodium hydroxide (NaOH) and hydrogen gas (Na=23, O=16, H=1), Find:-
a- The no. of sodium ions resulted from the reaction
b- The volume of evolving hydrogen gas

7- Calculate the molar mass of gaseous phosphorus in STP conditions, and the no. of atoms in one mole of it.

3- Balance the following equations

1- $N_{2(g)} + H_{2(g)} \rightarrow \Delta\ NH_{3(g)}$

2- $Cu(NO_3)_{2(s)}\ \Delta \rightarrow CuO_{(s)} + NO_{2(g)} + O_{2(g)}$

3- $3\ Al_{(s)} + O_{2(g)}\ \Delta\rightarrow Al_2O_{3(s)}$

4- Represent the following reactions by balanced ionic equations

1- The reaction of sodium chloride with silver nitrates forming a white ppt. of silver chloride and sodium nitrates

2- The reaction of Nitric acid with potassium hydroxide solution forming potassium nitrate solution and water



1- Choose

1- 28gm

→ The molar mass of calcium carbonate = 40 + 12 + 16+16+16 = 100 gm
The molar mass of calcium oxide (CaO) = 40+16 = 56
The no. of moles = the mass of the sample/ the molar mass = 50/100 = 0.5 mol
1 mole of calcium carbonate → 1 mole of calcium oxide CaO
0.5 mole of calcium carbonate → 0.5 mole of calcium oxide CaO
The mass of calcium oxide = 0.5 x molar mass = 0.5 x 56 = 28g

---

2- 11.2 L

$$2H_2 + O_2 \rightarrow 2H_2O$$

2 moles of hydrogen → 2 moles of water
The volume of hydrogen gas = the volume of water
The volume of water = 11.2 L
The volume of hydrogen gas = 11.2 L

3- $1.66x10^{-24}$

4- Mole

5- 34g

→ The molar mass of ammonia gas = 14+1+1+1= 17gm
The no. of moles = the volume of gas in STP / 22.4 = 44.8/22.4 = 2 moles
The mass of 44.8 L of ammonia gas = no. moles x molar mass = 2 x 17 = 34g

---

6- 11.5gm

→ the molar mass of sodium = 23 gm
The no. of moles = no. of atoms / Avogadro's number = 0.5 mol.
The mass of sodium = 0.5 x 23 = 11.5 gm

7- law of mass conservation

8- 22 g

→ The molar mass of carbon dioxide gas = 16 + 16+12 = 44g
The mass of carbon dioxide = 0.5 x 44 = 22g

9- 89.6 L

$$2H_2 + O_2 \rightarrow 2H_2O$$

Molar mass of oxygen O_2 = 16+16 = 32 gm
The no. of moles = 64 / 32 = 2 moles
1 mole of oxygen → 2 moles of water
2 moles of oxygen → 4 moles of water
The volume of water vapour in STP = 22.4 x the no. of moles = 22.4 x 4 = 89.6L

10- 2 moles

11- $12.04x10^{23}$ molecules

→ *The molar mass of sulphur oxide = 32 +16+16 = 64 g*
The no. of moles = 128/64 = 2 moles
The no. of molecules = no. of moles x Avogadro's no. = $12.04 x 10^{23}$ molecules

---

12- $6.02 x 10^{23}$ ions

One mole of sodium hydroxide = 23 + 16+1 = 40g
One mole of NaOH → one mole of sodium ions
The no. of ions = $6.02 x 10^{23}$ ions

13- 44.8 L

→ *The molar mass of hydrogen gas = 2g*
The no. of moles = 4/2 = 2 moles
The volume of gas in STP = 2 x 22.4 = 44.8 L

14- Gay-Lussac's law

<u>Solve the following problems</u>

1- The molar mass of sodium chloride = 23+35.5 = 58.5
The no. of moles in 117 gm of NaCl = 117/58.5 = 2 moles
One mole of NaCl → One mole of sodium positive ions
Two moles of NaCl → Two moles of sodium positive ions
The no. of sodium ions = 2 x $6.02 x 10^{23}$ = ***<u>$12.04 x 10^{23}$ ions</u>***

2- Na_2CO_3 +2 HCl → NaCl +H_2O+ CO_2

a- The no. of water molecules

The molar mass of sodium carbonate = 23+23+16+16+16+12 = 106g
The no. of moles in 26.5 g = 26.5 / 106 = 0.25 mole
One mole of Na_2CO_3 → one mole of water
0.25 mole of Na_2CO_3 → 0.25 mole of water
The no. of water molecules = 0.25 x $6.02 x 10^{23}$ = ***<u>$1.505 x 10^{23}$ molecules</u>***

b- The volume of CO_2 gas in STP conditions

One mole of Na_2CO_3 → one mole of carbon dioxide
0.25 mole of Na_2CO_3 → 0.25 mole of carbon dioxide

The volume of the gas = 0.25 x 22.4 = ***5.6 Litres***

3- The molar mass of carbon element = 12+12 = 24
(N.B: the molar masses of diatomic nonmetal elements are calculated this way)
The no. of moles in 144 gm of carbon = 144/24 = 6 moles

4- The molar mass of $CaCO_3$ = 40+12+16+16+16= 100g
The mass of 2.4 moles = 100 x 2.4 = 240 g

5- The molar mass of nitrogen gas = 14+14=28 gm
The no. of moles in 56 g = 56/28 = 2 moles
The volume of nitrogen gas in STP conditions = 22.4 x 2 = 44.8 L

6- $2Na + 2H_2O \rightarrow 2NaOH + 2\ H_2O$

a- the no. of sodium ions
The molar mass of sodium = 23 g
One mole of sodium → one mole of sodium hydroxide solution → one mole of sodium ions
The no. of ions = 6.02×10^{23} ions

b- The volume of hydrogen gas in STP conditions
One mole of sodium → one mole of hydrogen gas
The volume of hydrogen gas in STP conditions = 22.4L

7- Gaseous phosphorus molecule consists of 4 atoms
The molar mass of gaseous phosphorus = 4 x 31 = 124 gm
The no. of atoms in one mole = Avogadro's no. x the no. of atoms per molecule
= $6.02 \times 10^{23} \times 4$ = 24.08×10^{23} atoms

<u>Balance the following equations</u>

1- $N_{2(g)} + H_{2(g)} \rightarrow \Delta\ NH_{3(g)}$

The no. of hydrogen atoms on the right side of the equation is 3, while that on the left side of it is 2. To balance the no. of hydrogen atoms on both sides, we increase it on both of them to 6

$$N_{2(g)} + 3\ H_{2(g)} \rightarrow \Delta\ 2NH_{3(g)}$$

2- $Cu(NO_3)_{2(s)}\ \Delta \rightarrow CuO_{(s)} + NO_{2(g)} + O_{2(g)}$

There are 2 nitrogen atoms on the left side of the equation, while there is only 1 nitrogen atom on the right side of it. To balance the no. of nitrogen atoms, we increase the no. of nitrogen atoms on the right side to 2

$$Cu(NO_3)_{2(s)} \Delta \rightarrow CuO_{(s)} + 2NO_{2(g)} + O_{2(g)}$$

3- $Al + 3\ O_2 \rightarrow Al_2$

*we find that there are 3 oxygen atoms on the right side of the equation, while there are only 2 on the left side of it. To balance the no. of oxygen atoms on both sides, we should increase the no. of oxygen atoms on both of them to 6 (**6 is the least common multiple of 2 and 3)***

$$Al + 3\ O_2 \rightarrow 2\ Al_2O_3$$

There are four aluminium atoms on the right side of the equation, while there's a single atom on the left size. To balance the no. of aluminium atoms on both sides, we increase the no. of atoms in left size to 4 aluminium atoms

$$4Al + 3\ O_2 \rightarrow 2\ Al_2O_3$$

4- Ionic equations

1- $NaCl_{(aq)} + AgNO_{3(s)} \rightarrow NaNO_{3(aq)} + AgCl_{(s)}$

$$Na^+_{(aq)} + Cl^-_{(aq)} + Ag^+_{(aq)} + NO_3^- \rightarrow Na^+_{(aq)} + NO_3^- + AgCl_{(s)}$$

→ Sodium and nitrate ions are omitted from both sides because they do not react with any other ions. As sodium nitrates on right hand side is an aqueous solution (aq)

$$Cl^-_{(aq)} + Ag^+_{(aq)} \rightarrow AgCl_{(s)}$$

2- $HNO_{3(aq)} + KOH_{(aq)} \dashrightarrow KNO_{3(aq)} + H_2O_{(l)}$

$$H^+_{(aq)} + NO_3^- + K^+_{(aq)} + OH^-_{(aq)} \rightarrow K^+_{(aq)} + NO_3^- + KOH_{(s)}$$

→ Potassium and nitrate ions are omitted from both sides because they do not react with any other ions. As potassium nitrate on right hand side is an aqueous solution (aq).

$$K^+_{(aq)} + OH^-_{(aq)} \rightarrow KOH_{(s)}$$

Lesson (2)
The calculation of chemical reactions



Weight percent

The weight percent of a substance = 100x the mass (or the mole) the substance / the mass of (or the mole) the compound

Example

Calculate the weight percent of oxygen in carbon dioxide gas (C=12,O=16)

Solution

The mole of carbon dioxide CO_2 *= 12+16+16=44 gm*

The mass of oxygen atoms forming CO_2 *mole = 16 + 16 = 32 gm*

The weight percent of oxygen = (32 / 44)x 100 = 72.7%

Example (2)

Calculate the mass of iron in 1000 kg of hematite (Fe_2O_3) *(if the weight percent of Fe equals 58%)*

Solution:-

The mass of iron = 58% x 1000 = 580 kg

Example (3)

Calculate the weight percent of iron in ferric oxide (Fe_2O_3) *(Fe=56, O=16)*

Solution:-

Mole of ferric oxide = 56+56+16+16+16 = 160 gm

The mass of iron atoms forming one mole of ferric oxide = 56 + 56 = 112 gm

Weight percent of iron = (112/160) x 100 = 70%

Example (4)

Calculate the no. of carbon moles in an organic compound containing only hydrogen and carbon atoms. The weight percent of carbon = 85.71% and the molar mass of the compound = 28 gm (C=12)

Solution:-

The mass of carbon in this compound = 85.71% x 28 = 24 gm
The molar mass of carbon = 12 gm
The no. of carbon moles = 24 / 12 = 2 moles

Calculating chemical formula

Chemical formulas have two main kinds:-

1- Empirical formula
2- Molecular formula

***Empirical formula:** The formula that describe the simplest ratio between the atoms of the elements forming the compound molecules*

Example:-

*The formula of Propylene is C_3H_6, if we divided both numbers by 3, the empirical formula will be CH_2 (**empirical formula describes only the ratio between the components of molecules**)*

<u>How to calculate chemical formula</u>

We can calculate them using the weight percents of the elements forming the compounds

Example:-

Calculate the empirical formula of a compound containing 25.9% nitrogen and 74.1% oxygen (O=16, N=14)

Solution:-

The no. of nitrogen moles = weight percent /molar mass = 25.9/14 = 1.85 mol.
The no. of oxygen moles =weight percent / molar mass = 74.1 / 16 = 4.63 mol.

Nitrogen : Oxygen
1.85 : 4.63
1.85 : 1.85
1 : 2.5

So, the ratio between Nitrogen and oxygen = 1 : 2.5 (we multiply both sides by 2 because decimals such as "2.5" cannot be used in chemical formulas) = 2 : 5
The chemical formula = N_2O_5

***The no. chemical formula units =** The molar mass of compound / the molar mass of chemical formula units*

Molecular formula: *The symbolic formula of the molecule of a compound which describes the kind and the actual no. of the atoms forming that molecule*

Example:-

Acetic acid of weight 60 gm contains 40% carbon, 6.67% hydrogen and oxygen 53.33%
(C=12, O=16, H=1). Calculate its molecular formula

Solution:-

Oxygen	: Hydrogen	: Carbon
$\frac{53.33}{16}$	$\frac{6.67}{1}$	$\frac{40}{12}$
3.33	6.67	3.33
1	2	1

The empirical formula: *CH_2O*

The molar mass of Acetic acid = 12 + 1+1+16 = 30 gm

The no. of units = 60/30 = 2 units

The molecular formula = *$CH_2O \times 2 = C_2H_4O_2$*

Actual and theoretical yields

When a chemical reaction occurs to get certain amount of chemical substances, the chemical equation of the reaction determines theoretically the amount of the products. But practically, the amount of the products will be less than the theoretical amount because:-

1- The products may be volatile and parts of them spread in the air
2- Parts of the products may stick to the glass containers walls
3- The reactants may be impure
4- side reactions may occur

Practical yield: *The amount of substances we get practically from the reaction*

Theoretic yield: *The amount of substances we expect to get form the reaction*

The percentage yield ***(the percentage of practical yield)***

$$100 \times \frac{\text{Practical yield}}{\text{Theoretical yield}}$$

Example:-

39.4 gm of solid barium sulphate $BaSO_4$ precipitated when 40 gm of barium chloride solution $BaCl_2$ reacted with potassium sulphate. Calculate the percentage yield of barium sulphate

Solution

$$2BaCl_2 + 2KSO_4 \rightarrow 2BaSO_4 + 2KCl$$

Mole of $BaCl_2$ = 137 + 35.5 + 35.5 = 208 gm

Mole of $BaSO_4$ = 137 + 32 + 16+16+16+16 = 233 gm

The no. of $BaCl_2$ moles = mass of substance / molar mass = 40/208 = 0.19 mol

2 moles of $BaCl_2$ → 2 moles of $BaSO_4$
0.19 mole of $BaCl_2$ → 0.19 mol of $BaSO_4$

The mass of $BaSO_4$ = 0.19 x molar mass = 0.19 x 233 = 44.8 gm

The practical yield = 39.4 gm

The theoretical yield = 44.8 gm

The percentage yield = the practical yield / the theoretical yield x 100
= 39.4/44.8 x 100 = 87.95%

Definitions of lesson (2)

Empirical formula: *The formula that describe the simplest ratio between the atoms of the elements forming the compound molecules*

Molecular formula: *The symbolic formula of the molecule of a compound which describes the kind and the actual no. of the atoms forming that molecule*

Practical yield: *The amount of substances we get practically from the reaction*

Theoretical yield: *The amount of substances we expect to get form the reaction*

Give reasons for

8- The actual (practical) yield is always less than the theoretical yield

Because the reactants may be impure, side reactions may occur, the products may be volatile and spread in the air, or they can stick to the glass containers walls

Exercises on lesson (2)

1- Choose

1- The empirical formula of $C_4H_8O_2$ is............

A- C_2H_4O B- C_4H_2O C- CH_4O_2 D- $C_2H_8O_2$

2- The no. of empirical formulas in $C_2H_2O_4$ is .....

A-1 B-2 C- 3 D-4

3- If the empirical formula of a compound is CH_2 and its molar mass if 56g, its molecular formula is.....

A- C_2H_4 B- C_4H_8 C- C_3H_6 D- C_5H_{10}

4- If the molecular formula of Vitamin C is $C_6H_8O_6$, its empirical formula is....

A- $C_3H_4O_3$ B- $C_3H_4O_6$ C- $C_3H_8O_3$ D- C_3H_6O

5- The empirical formula CH_2O describes......

A- CH_3 COOH B- $C_6H_{12}O_6$ C- HCHO D- All the previous answers

6- The hydrocarbon compound formed from the reaction of 0.1 mol. of carbon atoms with 0.4 mol. of hydrogen atoms is......

A- CH_4 B- C_2H_4 C- C_4H_8 D- C_3H_8

2- Write the scientific term

1- A method to describe chemical formula, the quantities of reactants and products, and the conditions for chemical reaction

2- The mass of atoms or molecules in grams

3- A constant no. of the ions, molecules or atoms in one mole of matter

4- A formula describes the actual no. of atoms in molecules

5- The amount of matter we get practically from the reaction

6- The sum of the atoms masses forming the molecule

7- The volumes of the reactant and products gases have certain ratios

8- The equals volume of gases in the same conditions of temperature and pressure have the same no. of molecules

9- A formula which describe the simplest ratios between the atoms forming molecules

10- The amount of reactants we expect to get from the reaction

3- Solve the following problems

1- Find the molecular formula of a compound containing 85.7% carbon and 14.3% hydrogen whose molar mass is 42g

2- 130g of silver chloride (AgCl) precipitated when a mole of sodium chloride (NaCl) reacted with silver nitrates ($AgNO_3$), calculate the percentage yield (percentage of actual yield)   (Ag=108, N=14, Cl= 35.5, Na= 23,O=16)

3- Calculate the weight percent of iron in $FeCO_3$ (Fe=56, C=12, O=16)

4- Calculate the weight percent of the elements forming Glucose sugar $C_6H_{12}O_6$ (C=12, H=1, O=16)

The answers

1- Choose the correct answer

1- C_2H_4O

2- 2

3- C_4H_8

The molar mass of CH_2 the empirical formula = 12+1+1 = 14g
The no. of units = molar mass of the compound / the molar mass of the empirical formula = 56/14 = 4 units
The molecular formula = 4 x CH_2 = C_4H_8

4- $C_3H_4O_3$

5- All the previous answers

6- CH_4

*2- **Write the scientific term***

1- Chemical reaction
2- Mole
3- Avogadro's number
4- Molecular formula
5- Practical yield
6- Molecular mass
7- Gay-Lussac's law
8- Avogadro's law
9- Empirical formula
10- Theoretical formula

Solve the following problems

1-

Hydrogen :	Carbon
$\frac{14.3}{1}$	$\frac{85.7}{12}$
14.3	7.1416
2	1

The empirical formula: CH_2

The molar mass of the compound = 12 + 1+1+ = 14 gm

The no. of units = 42/14 = 3 units

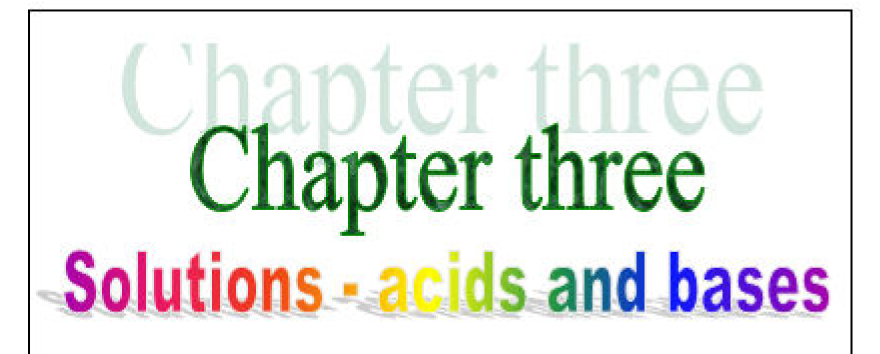
The molecular formula = $CH_2 \times 3 = C_3H_6$

2- $NaCl_{(aq)} + AgNO_{3\,(aq)} \rightarrow NaNO_3 + AgCl_{(s)}$

Mole of sodium chloride = 23+35.5 = 58.5
Mole of silver chloride = 108+58.5 = 143.5
The practical yield = 140g
The theoretical yield = 143.5g
The percentage yield = 140/143.5 x 100 = 97.56%

3- The molar mass of $FeCO_3$ = 56+12+16+16+16 = 116g
The mass of iron forming one mole of $FeCO_3$ = 56g
The weight percent = 56/116 x 100 = 48.26%

4- The molar mass of glucose = 12x6 + 12x1 +16x6 = 72+12+96 = 180g
The mass of carbon = 12x6 = 72g
The mass of hydrogen = 12x1 = 12g
The mass of oxygen = 16x6= 96g
The weight percent of carbon = 72/180 x 100 = 40%
The weight percent of hydrogen = 12/180 x 100 = 6.7%
The weight percent of oxygen = 96/180 x 100 = 53.3%



Lesson (1) Solutions and colloids

Lesson (2) Acids and bases

Lesson (1) solutions and colloids



When we add salt or sugar to water, they dissolve in it forming homogenous mixtures called " ***solutions".*** *But if we put them in gasoline or kerosene, they don't dissolve in any of them (they don't mix) and we can distinguish their components by naked eyes, such non homogenous mixtures are called "****Suspensions****"*

Some mixtures have the properties of both solutions and suspensions, they are called ***"Colloids"*** *(milk, mayonnaise, aerosols, hair gel, blood...etc)*



Water and oil (suspension)



Milk (colloid)



Cobalt chloride solution



Solutions

The importance of solutions

1- They're essential for the biological processes inside living organisms
2- They're important for the occurrence of some chemical reactions

→ *The substances forming solutions are regularly distributed in all the solution parts*

True solution: *A homogenous mixture of two or more substances*

The substance which exists in greater amount in solutions are called" ***solvents"****, while substances that exist in smaller amounts and dissolve in solvents are called* ***"solutes"***

Solutions are classified according to the physical state of both solute and solvent

Solution type	Solvent type	Solute type	Examples
gas	gas	gas	-Air -Natural gas
gas	gas	liquid	-Water vapour in air - gasoline mixture in air
gas	gas	solid	Naphthalene in air
liquid	liquid	gas	- Dissolved oxygen in water - Fizzy drinks
liquid	liquid	liquid	- Alcohol in water - ethylene glycol(**anti-freezing)** in water
liquid	liquid	solid	- salt of sugar in water
Solid	solid	gas	-Hydrogen in palladium and platinium
Solid	solid	liquid	- silver amalgam $Ag_{(s)}$ / $Hg_{(l)}$
Solid	solid	solid	- alloys (**Nickel-chrome alloy)**

Some important concepts

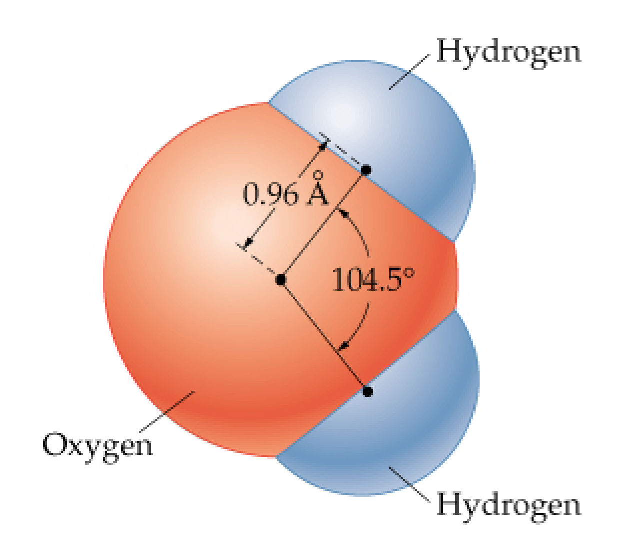
Electronegativity: *The ability of atom to attract electrons*

Polar bond: *A type of covalent bond between two atoms in which electrons are shared unequally (**the greater atom carries a negative charge**)*

Polar molecule: *A Molecule which has a bond carrying molecular positive charge and another one carrying molecular negative charge*

The bonds in water molecules are polar because the negative charge (electronegativity) of oxygen is greater than that of hydrogen. Thus, oxygen atom carries molecular negative charge, while hydrogen atoms carry molecular positive charges.

→ *The angle between the two bond of water molecule equals 104.5◦*



*Design of water molecule (**the angle between the two bonds = 104.5◦**)*

Electrolyte and non electrolyte solutions

Electrolytes: *Substances whose solutions can conduct electric current via the movement of free ions*

Electrolytes are divided into:-

***Strong Electrolytes**: Electrolytes that completely disassociate in water (all their molecules disassociate into ions) which makes them high conductors of electricity*

***Examples**:-*

→ ***Ionic compounds**: sodium chloride (NaCl) and sodium hydroxide (NaOH)*
→ ***Polar covalent compounds**: Hydrochloric acid (HCl) (**it conducts electricity if it's a solution, not in gaseous state)***

When hydrochloric acid dissolves in water, positive hydrogen ions are produced and bond with water molecules forming hydronium (H_3O^+)

$$HCl_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

***Weak Electrolytes:** Electrolytes that partially disassociate in water (small no. of its molecules disassociate in water) which makes them low conductors of electricity*

Examples:-

→ *Acetic acid CH_3COOH (vinegar)*
→ *Ammonium hydroxide (ammonia solution) NH_4OH*
→ *Water H_2O*

***Non electrolytes:** Substances whose solutions cannot conduct electricity because of the absence of free ions*

Examples on non electrolytes:-

→ *Sugar*
→ *Ethyl alcohol (ethanol)*

Dissolution Process

***Dissolution process:** The process in which the solute molecules disassociate into negative ions, positive ions, or separated polar molecules and then get surrounded by the molecules of solvent*

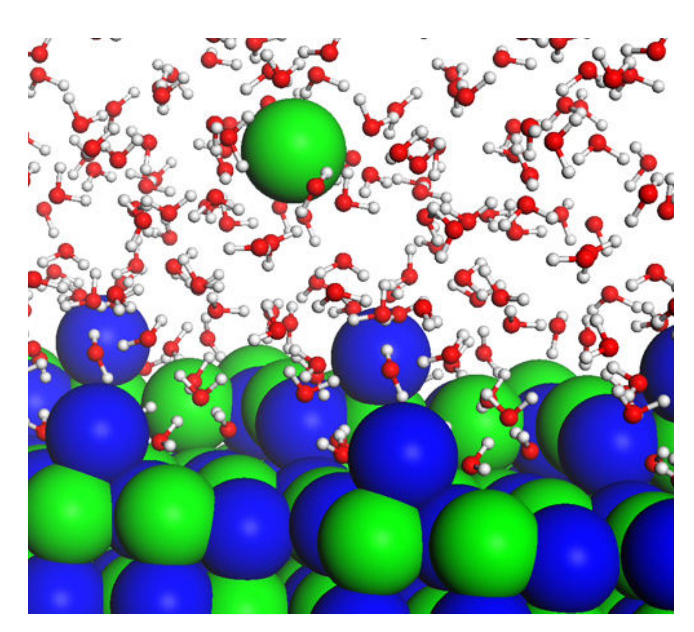
Polar and ionic compounds dissolve easily in water, while non polar molecules (fats, oil, methane…etc) don't dissolve in water (but dissolve in benzene).

To know how dissolution process occur, we should know that water molecules are in continuous motion due to their kinetic energy

When putting an ionic compound crystal (such as NaCl) in water, water molecules collide with the crystal and attract its ions. This process is the dissolution process

→ *A true solution is composed of regularly-distributed ions or molecules whose diameters range from 0.01 nm to 1 nm. This makes the solution homogenous and allows light to penetrate it*

→ *When putting little sugar in water, the polar molecules of sugar gets separated and bond to those of water by* ***hydrogen bond*** *forming sugar solution*



The process of salt dissolution in water

→ *Dissolution process can be controlled by* ***surface area, stirring and heat***

How does oil dissolve in benzene

Both of oil and benzene are polar compounds whose bonds are weak. So when we add oil or benzene, the molecules of oil spread in the molecules of benzene



The ability of a solute to dissolve in solvent **or** *the ability of solvent to make solute dissolve in it*

Solubility: *The mass of solute dissolving in 100g of solvent at certain temperature*

Factors affecting solubility

1- The nature of solvent or solute
2- The temperature

→ *When dissolving 36.8g of sodium chloride in water at temperature of 25◦C , the solvent becomes saturated.*

→ *In saturated solutions, no additional amounts of solutes can dissolve in them because the ions of the additional amounts replace the ions bonded to water molecules, Therefore, these ions precipitate in the form of crystalline solid substance in solution*

→ *A saturated solution is in a state of dynamic equilibrium because the rate of dissolving is equal to that of precipitation*

Solutions can be classified according to saturation into:-

Unsaturated solutions: *Solutions that allow additional amounts of solute to dissolve in them at certain temperature*

Saturated solutions: *Solutions that doesn't allow the dissolution of any additional amounts of solute without change in temperature*
Super saturated solutions: *Solutions that allow the dissolution of additional amounts of solute when heating.*

→ *When super saturated solutions cool down, the ions of the additional amount of solute gets separated and precipitates in the form of crystalline solid substance*

→ *The solubility of most solid substances increases by the increase of the temperature of the solvent. For example, the solubility of NaCl increase to 41g at temperature of 80◦C*

→ *The solubility of sodium chloride at 25◦C is 36.8g*

Thermal changes associated with dissolution process

Formation of solutions process sometimes cause a change in temperature,

Endothermic solutions: *Solutions which absorb energy (heat) when they are formed*

Example: *When dissolving potassium iodide (KI) in water, it absorbs energy* ***(the glass container of KI solutions cools down)***

Exothermic solutions: *Solutions which give away energy (heat) when they are formed*

Examples: *When dissolving sodium hydroxide (NaOH) in water, it gives away energy (heat)*

The concetration of solutions

*In order to calculate the concentration of solutions, we should calculate the concentration of the substances forming them. It's said that a solution is "**concentrated**" if the quantity of solute is greater than usual (**But not greater that the quantity of solvent**)*

The methods of calculation of the concentration of solutions

1- Percent concentration
2- Molarity (M)
3- Molality (m)

Percent concentration

It calculates the concentration of solutions in percent

The percent concentration is calculated by two ways:-

(volume-volume) percent concentration : *It calculates the concentration of solutions in percent according to the volumes of solvent and solute*

$$\text{Volume- volume percent concentration} = 100 \times \frac{\text{The volume of solute}}{\text{The volume of solvent}}$$

The volume of solution = the volume of solute + the volume of solvent

(mass-mass) percent concentration: *It calculates the concentration of solutions in percent according to the masses of solvent and solute*

Mass-mass percent concentration = 100 x $\frac{\text{The mass of solute (grams)}}{\text{The mass of solvent (mililitre)}}$

The mass of solution = the mass of solute + the mass of solvent

Because of the existence of various kinds of percent concentration, labels are put on different products to describe its percent concentrations

Molarity (M)

Molarity: *The no. of moles of solute dissolved in one litre of solvent*

The measuring unit of Molarity (M) is mol/gm or Molar (M)

Molarity (M) = 100 x $\frac{\text{No. of moles (mol)}}{\text{Volume of solution (L)}}$

Example :-

Calculate the molar concentration of sodium chloride solution if the mass of dissolved sodium chloride (NaCl) equals 117g and the volume of water equals 320 mL

Solution:-

One mole of NaCl = 23 + 35.5 = 58.5g

The no. of moles dissolved in 320 ml. of water = 117/58.5 = 2 mol.

320 ml = 0.32 L

The molar concentration of the solution = no. of moles / volume of solution

= 2 / 0.32 = ***6.25mol/L***

Example (2):-

Calculate the Molarity of sugar solution $C_{12}H_{22}O_{11}$ *if the mass of dissolved sugar equals 85.5g and the volume of solution equals 0.5L (C=12, H=1,O=16)*

Solution:-

The molar mass of sugar = 12x12 + 22x1 + 16x11 = 342g
The no. of sugar moles = 85.5/342 = 0.25 mol

The molar concentration = the no. of moles / volume of solution
= 0.25 / 0.5 = ***0.5 mol./L***

Molality (m)

Molality (m): *The no. of moles of solute dissolved in one kilogram of solvent*

The measuring unit of Molality equals mol/kg

$$\text{Molality (m)} = 100 \times \frac{\text{The no. of solute moles}}{\text{The mass of solvent (kg)}}$$

Example

Calculate the Molality of a solution prepared from the dissolution of 20g of sodium hydroxide NaOH in 800g of water H_2O (Na=23, O=16, H=1)

Solution:-

The molar mass of NaOH = 23+16+1= 40g
The no. of moles in 20g of NaOH = 20/40= 0.5 mol.
800g of water = 0.8 kg
The molality of the solution = the no. of moles / the mass of solvent
= 0.5 / 0.8 = ***0.625 mol/kg***

Some properties of solutions

Some of the properties of pure solvent are different from those of solutions
→ Vapour pressure, freezing point and boiling point are examples on these properties

Vapour pressure and boiling point

Vapour pressure: *The pressure exerted by vapour when it becomes in state of equilibrium with the liquid inside a closed container at constant temperature and pressure*

When the rates of condensation and evaporation of a liquid inside a closed container become equal, a state of equilibrium happens between the vapour above the liquid and its pressure

→ *Vapour pressure depends on the temperature of the liquid (**when the temperature increases, both of the evaporation rate and vapour pressure increase)***

→ *When vapour pressure becomes equal to the atomic pressure due to the increase of temperature, the solution begins boiling, which is known as "**natural boiling point"***

→ *Natural boiling point can prove the purity of liquids*

*In pure solvents, the molecules exposed to evaporation process are not affected by any forces but the attractive forces between them. But when adding solutes to the solvent, the vapour pressure decreases **because the solutes molecules become exposed to evaporation process** , which decreases the surface area. Moreover, the attraction forces between the solution molecules increase*

→ *Vapour pressure depends on the no. of the solution molecules, not its properties and structure*

Boiling point: *The temperature at which the vapour pressure of solution becomes equal to the atomic pressure*

→ *The boiling point of pure water is 100◦C , but it increases in other solutions (such as salt solution) because the solute particles decrease the no. of water molecules escaping from the surface of water, which decreases vapour pressure. Therefore, water molecules need more energy which increases the boiling point. The same occurs to any nonvolatile solute dissolves in any solvent*

Freezing point

→ *Adding nonvolatile solutes to solvents decreases the solutions freezing points* *because they increase the attraction forces between the solute particles and the solvent molecules, which prevents the solvent from turning into solid state*

→ *Salts are put on roads in winter to prevent them from freezing, which decreases the rate of the occurrence of car accidents*

→ *The decrease of freezing points depends on the no. of the particles of the solute, not their structures*

→ *When adding one mole of glucose sugar (180g) to 1000g of water, the resulted solution freezes at -1.86◦C* ***(not at zero degree as in pure water) because dissolution process produces one mole of particle****s*

→ *When adding one mole of sodium chloride (58.5g) to 1000g of water,* ***2 moles of ions (one mole of sodium ions and another on of chlorine ions) are produced, which doubles the decrease of freezing points to be = 2 x -1.86◦C = -3.72◦C***

Calculate the freezing point of a solution containing one mole of calcium chloride $CaCl_2$ and 1000g of water

Suspensions

They are non homogenous mixtures whose solid particles precipitate and can be distinguished by naked eye or microscope (the solute and solvent don't mix). The diameter of each precipitated solid particle equals 100nm. The components of suspensions can be separated using ***"filter papers"*** *. The process of separating between the components of suspensions is known as "****Filtration process"***

Examples of suspensions:-

1- Water and oil mixture
2- Water and chalk mixture
3- Water and sand mixture



Colloids: *Non homogenous mixtures whose particles don't precipitate and they are hard to be separated using filter papers*

→ *the diameter of each particle forming true solutions in colloids is less than 1 nm, while that of each molecule forming suspensions in collides is more than 100 nm* ***(we can say that the diameters of the particles forming colloids range from 1 nm to 100nm)***

Colloidal systems

Colloids are classified according to ***the dispersed substance*** *and* ***the medium of dispersion***

→ *The dispersed substance is the suspension in the colloid, while the medium of dispersion is the medium which contains the dispersed substances*

Dispersed substance	***Medium of dispersion***	***Colloid***
gas	*Liquid*	*Some kinds of creams*
gas	*Solid*	*Some kinds of sweets such as* ***gelatin*** *and* ***jelly***
liquid	*liquid*	*Milk and Mayonnaise*
liquid	*gas*	*Aerosols (hair sprays)*
Solid	*gas*	*Dust in air*
Solid	*gas*	*Blood – hair gel – starch in water - paints*

Some examples on colloidal systems

Properties of colloids

A lot of concentrated colloids resemble milk in its shape and seem pure (especially in low concentrated colloids). Particles of colloids cannot be separated by using filter papers

How to prepare colloids

Colloids are prepared by two methods

1- Diffusion method: We fragment substances into small pieces of sizes equal to those of colloids. Then, we add them to the medium of dispersion and stir the mixture

*2- Condensation method: We add small particles to greater suitable molecules by means of some chemical process such as **Oxidation, Reduction** and **Hydrolysis***

***Hydrolysis** (for reading only) : Breaking down the chemical bonds in water molecules forming hydrogen ions (H) and hydroxyl ions (-OH) in some chemical reactions*

Definitions of lesson (1)

***True solution:** A homogenous mixture of two or more substances*

***Electronegativity:** The ability of atom to attract electrons*

Polar bond:** A type of covalent bond between two atoms in which electrons are shared unequally (**the greater atom carries a negative charge)

***Polar molecule:** A Molecule which has a bond carrying molecular positive charge and another one carrying molecular negative charge*

***Electrolytes:** Substances whose solutions can conduct electric current via the movement of free ions*

***Non electrolytes:** Substances whose solutions cannot conduct electricity because of the absence of free ion*

***Solubility:** The mass of solute dissolving in 100g of solvent at certain temperature*

***Dissolution process:** The process in which the solute molecules disassociate into negative ions, positive ions, or separated polar molecules and then get surrounded by the molecules of solvent*

***Unsaturated solutions:** Solutions that allow additional amounts of solute to dissolve in them at certain temperature*

***Saturated solutions:** Solutions that doesn't allow the dissolution of any additional amounts of solute without change in temperature*

***Super saturated solutions:** Solutions that allow the dissolution of additional amounts of solute when heating.*

***Endothermic solutions**: Solutions which absorb energy (heat) when they are formed*

***Exothermic solutions:** Solutions which give away energy (heat) when they are formed*

***Molarity:** The no. of moles of solute dissolved in one litre of solvent*

***Molality (m):** The no. of moles of solute dissolved in one kilogram of solvent*

***Vapour pressure:** The pressure exerted by vapour when it becomes in state of equilibrium with the liquid inside a closed container at constant temperature and pressure*

***Boiling point:** The temperature at which the vapour pressure of solution becomes equal to the atomic pressure*

***Colloids:** Non homogenous mixtures whose particles don't precipitate and they are hard to be separated using filter paper*



1- The importance of solutions
Because they are essential for the biological processes within living organisms and important for the occurrence of some chemical reactions

2- Water molecules are polar
Because the Electronegativity difference between oxygen and hydrogen atoms forming them is great

3- Sodium chloride solution is considered as strong electrolyte
Because sodium chloride molecules completely disassociate into ions when they dissolve in water, which give the solution the ability to conduct electricity

4- Acetic acid is a weak electrolyte
Because some of its molecules disassociate into ions when they dissolve in water, which makes them weak conductors of electricity

5- Ethyl alcohol is considered as electrolyte
Because it doesn't conduct electricity (as its molecules do not disassociate into ions)

6- The boiling point of sodium chloride solution (NaCl) is smaller than that of sodium carbonate (Na_2CO_3) although their masses are equal

Because the no. of ions produced from sodium chloride solution is less than that of sodium carbonate, and as we know, solute particles decrease the no. of water molecules escaping from the surface of solution. Therefore, water molecules need more energy which increases the boiling point

7- Adding nonvolatile solutes to solvents decrease the freezing point of the solution

because they increase the attraction forces between the solute particles and the solvent molecules, which prevents the solvent from turning into solid state

8- The dissolution of sugar in water forms a solution, while the dissolution of dry milk in water forms a colloid

Because sugar particles spread in all parts of water regularly forming homogenous mixture and they cannot be distinguished by naked eyes, whereas dry milk particles spread irregularly in water molecules and this non homogenous mixture has the properties of both solutions and suspensions (but its components cannot be separated by using filter papers)

Exercise on lesson (1)

1- Choose the correct answer

1- Water vapour in air is a gaseous solution of kind…..
A- gas in gas   B- gas in liquid   C- liquid in gas   D- solid in gas

2- The measure of the angle between the two bonds of water molecule equals..
A- 140   B-140.5   C- 108.5   D- 104.5

3- …… is from strong electrolytes
A- Benzene   B- H_2O C- $HCl_{(g)}$ D- $HCl_{(aq)}$

4- The measuring unit of molality (m) is ……
A- mol/kg   B- mol/L   C- g/L   D- g/eq.L

2- What's meant by

1- Solubility
2- Saturated solution
3- Boiling point (in terms of vapour pressure)

3- Solve the following problems

1- Calculate the percent concentration of sucrose in a solution containing 10g of sucrose and 240g of water

2- If we add 50 ml of water to 25 ml of ethanol (ethyl alcohol) calculate the percent concentration of ethanol in the solution.

3- Find the molar concentration of a sodium hydroxide solution of volume 200 ml containing 20g of sodium hydroxide (NaOH) (Na=23, O=16, H=1)

4- if 53g of sodium carbonate (Na_2CO_3) dissolved in 400g of water, calculate the molality of the solution (Na=23, O=16, C=12, H=1)

4- Determine the type of colloidal systems of the following

1- Mayonnaise
2- Dust in air

The Answers

1- Choose the correct answer

1- liquid in gas
2- 104.5
3- HCl $_{(aq)}$
4- mol/kg

3- Solve the following problems

1- percent concentration = 100 x (mass of solute / mass of solution) =
100 x (10/240) = 100x 0.24 = ***24%***

2- The volume of the solution = the volume of solute + the volume of solvent =
25 + 50 = 75 ml
The percent concentration of ethanol = 100 x (25/75) = 100 x 0.333 = 33.3%

3- The molar mass of sodium hydroxide = 23+16+1 = 40g
The no. of moles in 20g of sodium hydroxide = 20/40 = 0.5 mole
200 ml = 0.2 L
The molar concentration = (the no. of moles of solute / volume of solvent)
= 0.5/ 0.2 = 5/2 = ***2.5 mol/L***

4- The molar mass of sodium carbonate = 23+23+12+16+16+16= 106g
The no. of moles in 53g of sodium carbonate = 53/106 = 0.5 mole
400g = 0.4kg
The molality of the solution = the no. of moles of solute / the mass of solvent = 0.5/0.4 = ***1.25 mol/kg***

4- Determine the type of colloidal systems

1- Mayonnaise:-
Medium of dispersion: *Liquid*
Dispersed substance: *Liquid*

2- Dust in air
Medium of dispersion: *Gas*
Dispersed substance: *Solid*

Lesson (2)
Acids and Bases



→*Acids and bases play an important role in life. Acids are used in the industry of fertilizers, explosives, medicines, plastic, car motors, computers…etc. Bases are used in the industry of soap, detergents, medicines, dyes…etc*

Product	***Acids or bases forming it***
Sour fruits (lemon, orange, tomato)	*Ascorbic acid – Citric acid*
Dairy products (yoghurt, milk, cheese)	*Lactic acid*
Fizzy drinks	*Carbonic acid – Phosphoric acid*
Soap	*Sodium hydroxide*
Washing soda	*Hydrated sodium carbonate*
Baking soda	*Sodium bicarbonate*

Acid: *A Compound with sour taste which turn the colour of blue litmus paper into red*
- It reacts with metals forming hydrogen
- It reacts with carbonate or bicarbonate salts forming carbon dioxide gas
- It reacts with alkalis (bases) forming salt and water

Base (Alkali): *A compound with bitter taste and soap texture which turns the colour of red litmus paper into blue, it reacts with acids forming salt and water*

Theories which define acids and bases

The Arrhenius theory (1887)

Swedish scientist Arrhenius put this theory in late 19th century (1887 A.D) to define acids and bases as the following

Arrhenius acid: *The substance which disassociate in water producing one or more positive hydrogen ions (H^+)*

Arrhenius base: *The substance which disassociate in water producing one or more negative hydroxide ions (OH^-)*

Explanation:-

The electric conductivity of aqueous solutions of acids and bases is due to the presence of ions in them, when sodium chloride dissolves in water, it produces negative chlorine ions and positive hydrogen ones

$$HCl_{(aq)} \rightarrow H^{+}_{(aq)} + Cl^{-}_{(aq)}$$

→ *Sodium hydroxide disassociates in water producing positive sodium ions and negative hydroxide ones*

$$NaOH \rightarrow Na^{+} + OH^{-}$$

→ *The first to discover the disassociation of acids and bases into ions was Arrhenius. Disassociation process has different types:-*

$$H_2SO_4 \rightarrow H^{+}_{(aq)} + HSO_4^{-}{}_{(aq)}$$

$$HClO_4 \rightarrow H^{+}_{(aq)} + ClO_4^{-}{}_{(aq)}$$

$$KOH_{(aq)} \rightarrow K^{+}_{(aq)} + OH^{-}_{(aq)}$$

$$Ba(OH)_{2(aq)} \rightarrow Ba^{2+} + 2OH^{-}_{(aq)}$$

→ *In this theory, acids should contain hydrogen atoms, and bases should contain hydroxide group (as shown in the previous equations). The Arrhenius theory helps us explain "Neutralization reactions" – the reaction of acids with bases forming water and salts*

$$NaOH + HCl \rightarrow NaCl + H_2O$$

Remarks on the theory

1- Polar water molecule contains oxygen atom carrying molecular negative charge, while hydrogen atoms carry molecular positive charge. Therefore, water molecule will be affected by the ions in the aqueous solution one way or another. Scientists discovered recently that protons (positive hydrogen ions) cannot exist freely in aqueous solutions because they bond with water molecules forming hydronium ions (H_3O^{+})

2- some bases (such as ammonia) form alkaline solutions although they don't contain any hydroxide ions in them

The Bronsted-Lowry theory (1923)

*In 1923, The English scientist "**Thomas Lowry**" and Danish scientist "**Johannes Bronsted**" formulated their theory about acids and bases.*

Bronsted-Lowry acid: *The substance which lose positive proton (Hydrogen ion)* ***(Proton donor)***

Bronsted-Lowry base: *The substance which gains positive proton (Hydrogen ion)* ***(Proton acceptor)***

According to this theory, we can say that acid is the substance that gives proton to base, and base is the substance that takes proton from acid (which means that the reaction is the transfer of proton from acid to base)

$$A^{-} + HB^{+} \rightleftharpoons HA + B$$

Acid ***Base*** ***Conjugate base*** ***conjugate acid***

When an acid loses a proton, it turns into a "conjugate base", whereas when a base gains a proton, it turns into a "conjugate acid"

Conjugate base: *The substance formed when an acid loses a proton*

Conjugate acid: *The substance formed when a base gains a proton*

→ *When we dissolve HCl in water, Hydrochloric acid solution is an acid because HCl gives protons to water. Therefore, water is considered as base because it gains protons from HCl acid*

→ *Ammonia is considered as Bronsted-Lowry base because it accepts protons (proton acceptor) from compounds*

Lewis theory (1923)

Scientist Gilbert Newton Lewis formulated a more comprehensive theory about acids and bases, which states that:-

Lewis acid: *The substance that receives one or more electrons*

Lewis base: *The substance that gives away one or more electrons*

→ *When a positive hydrogen ion (H_{+}) binds with a negative fluorine one (Fl_{-}), Hydrogen ion is regarded as* ***"Lewis acid"*** *because it gives away electrons, while the fluorine ion is regarded as* ***"Lewis base"*** *because it takes electrons.*

The classification of acids and bases

Acids

<u>Acids can be classified according to the degree of their disassociation in water into:-</u>

***Strong acids**: They are acids which completely ionize in water (all their molecules disassociate in water into ions). Their solutions are high conductors of electricity **(strong electrolytes)** due to the presence of ions in them*

Examples:-

1- Nitric acid (HNO_3)
2- Hydrogen iodide acid (HI)
3- Sulphuric acid (H_2SO_4)
4- Hydrochloric acid (HCl)
5- Hydrobromic acid (HBr)
6- Perchloric acid ($HClO_4$)

Weak acids**: They are acids which partially ionize in water (some of its molecules disassociate into ions). Their solutions are low conductors of electricity **(weak electrolytes)

Examples:-

→ Acetic acid (vinegar) CH_3COOH

Acetic acid ionizes in water into hydronium ion and acetate ion

$$CH_3COOH + H_2O \rightarrow CH_3COO^- + H_3O^+$$

***N.B:** There's no relation between the strength of an acid and the no. of hydrogen atoms in its molecules.*

<u>Acids can be classified according to their sources into:-</u>

***Organic acids:** They are acids of organic origin (animal-plant) which are extracted form living organisms*

Examples:-
1- Formic acid (CH_2O_2)
2- Acetic acid
3- Lactic acid
4- Citric acid

5- Oxalic acid ($H_2C_2O_4$)

Mineral acids: *They are acids which don't have any organic origin. They are formed from nonmetal elements (chlorine, Nitrogen, Phosphorus, Oxygen…etc)*

Examples:-

1- Hydrochloric acid (HCl)
2- Phosphoric acid (H_3PO_4)
3- Perchloric acid ($HClO_4$)
4- Carbonic acid (H_2CO_3)
5- Nitric acid (HNO_3)
6- Sulphuric acid (H_2SO_4)

An acid can be classified according to no. of hydrogen atoms in its molecules (the basicity of acids) into:-

Monobasic acid: *It gives away one proton (hydrogen ion) when reacting with one molecule of base*

Examples:-

1- Hydrochloric acid (HCl)
2- Nitric acid (HNO_3)

Dibasic acid: *It may give away two protons (hydrogen ions) when reacting with two molecules of base*

Examples:-

1- Sulphuric acid (H_2SO_4)
2- Carbonic acid (H_2CO_3)
3- Oxalic acid

Tribasic acid: *It may give away three protons (hydrogen ions) when reacting with two molecules of base*

Examples:-

1- Phosphoric acid (H_3PO_4)
2- Citric acid



Bases can be classified according to their degree of disassociation in water into:-

Strong bases: *Bases which completely ionize in water and considered as strong electrolytes*

Examples:-

1- Potassium hydroxide (KOH)
2- Sodium hydroxide (NaOH)
3- Barium hydroxide $Ba(OH)_2$

Weak bases: *They are bases that partially ionize in water and considered as weak electrolytes*

Examples:-

1- Ammonium hydroxide (NH_4OH)

Bases can be classified according to their molecular structure into:-

Metal oxides:-

1- Iron oxide (FeO)
2- lead oxide (PbO)
3- Calcium oxide (CaO)
4- Magnesium oxide (MgO)
5- Sodium oxide (Na_2O)
6- Potassium oxide (K_2O)

Metal hydroxides:-

1- Potassium Hydroxide (KOH)
2- Sodium hydroxide (NaOH)
3- Calcium hydroxide $Ca(OH)_2$
4- Magnesium hydroxide $Mg(OH)_2$
5- Barium hydroxide $Ba(OH)_2$

Metal carbonates (or bicarbonates):-

1- Sodium bicarbonate ($NaHCO_3$)
2- Potassium bicarbonate ($KHCO_3$)
3- Sodium carbonate (Na_2CO_3)
4- Potassium carbonate (K_2CO_3)

→ *Bases which dissolve in water producing negative hydroxide ions are called "**Alkalis**"*

→ *We can say that **all alkalis are bases** but **all bases are not alkalis***

Determination of acids and bases

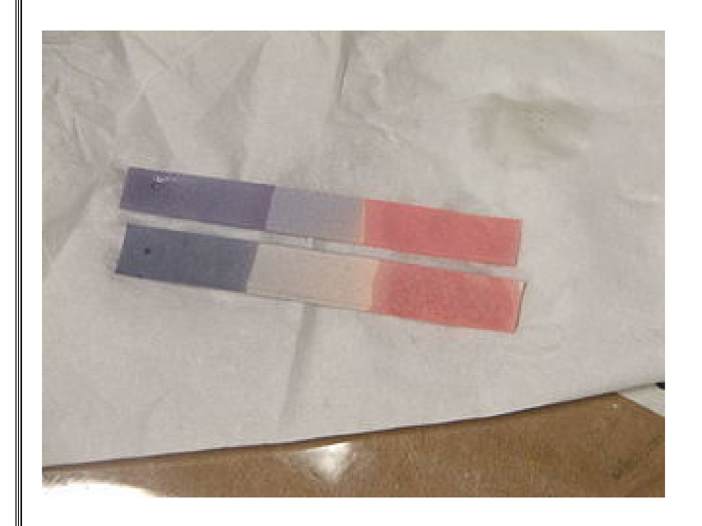
There are many ways to determine the acidity or basicity of a solution

Indicators

They are weak acids or bases whose colours change by the change of the kind of solution

→ *Acidic indicator is denoted by* ***HIn****, while basic indicator is denoted by* ***InOH***

The indicator	***In acids***	***In bases***	***In neutral solutions***
Methyl orange	*Red*	*Yellow*	*Orange*
Bromothymol blue	*Yellow*	*Blue*	*Green*
Phenolphthalein	*Colourless*	*Fuchsia*	*Colourless*
Litmus paper	*Red*	*Blue*	*Purple*



Litmus papers



Bromothymol blue



Methyl orange



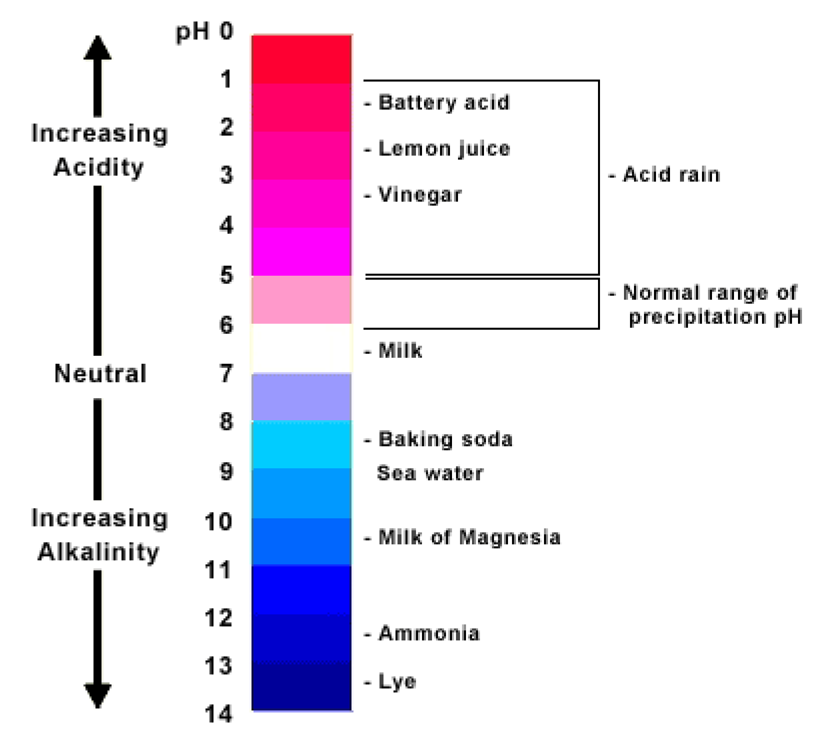
Phenolphthalein

Power of hydrogen (pH)

A method for determining the type of solution in numerical values ranging from 0 to 14. ***Papers*** *and* ***digital devices*** *are used to measure the pH of solutions*

N.B: *Read chapter (1) to know more about pH measurement*

→ *If the pH of a solution is less than 7, so its acidic*
→ *If the pH of a solution equals 7, its neutral*
→ *If the pH of a solution is greater than 7, so its basic*



pH indicator colour chart



How to form salts

The reaction of metals with diluted acids: *Metals which come before hydrogen in chemical activity series* ***(which we studied last year)*** *replace it in its diluted acids solutions forming salt and hydrogen gas*

$$Active\ metal + diluted\ acid \rightarrow Salt\ of\ acid + Hydrogen$$

$$Zn_{(s)} + H_2SO_4 \rightarrow ZnSO_4 + H_2 \uparrow_{(g)}$$

The reaction of metal oxides with acids: *This method is usually used in the case of the difficult of the reaction of metal with acid* <u>*due to the danger of reaction or the decrease of metal acitivity*</u>

$$Metal\ oxide + Acid \rightarrow water + salt\ of\ acid$$

$$CuO_{(s)} + H_2SO_4 \rightarrow CuSO_{4\,(aq)} + H_2O_{(l)}$$

The reaction of metal hydroxide with acids: *This method is valid in the case of soluble metal hydroxides, which are form Alkalis*

$$Acid + Alkali \rightarrow Salt + Water$$

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

Neutralization reaction: *The reaction of acids with alkalis forming water and salts*

The importance of neutralization reactions: *They are used in chemical analysis process in order to calculate the concentration of an acid or alkali using acids and alkalis with known concentrations in the presence of suitable indicators.*

The reaction of metal carbonates (or bicarbonates) with acids: *stable carbonate acid salts can be replaced by stable acids forming the new acid salt and carbon dioxide gas. This reaction is used to test acidity*

$$Na_2CO_{3\,(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2\,(g)} \uparrow$$

Nomenclature (Naming) of salts

Anion: *Negative ion*
Cation: *Positive ion*

→ *A salt is formed when the negative ion (anion) of an acid (Y^-) binds with the positive ion (cation) of a base (X^+) forming salt (XY). Thus, the chemical name of a salt is composed of two terms (Such as sodium chloride and potassium chloride)*

→ *The 1st term of salt chemical name describes the negative ion of acid (Anion) while the 2nd term describes the positive ion of base (Cation)*

→ *The chemical formula of a salt depends on the valency of the anions and cations forming them* ***(the following table mentions some acids, their structures, and the salts prepared by them)***

The acid	Anion	Salts prepared by acid
Nitric acid HNO_3	*Nitrates NO_3^-*	- *Potassium nitrate (KNO_3)* - *lead nitrate $Pb(NO_3)_2$* - *iron nitrate III $Fe(NO_3)_3$*
Hydrochloric acid HCl	*Chloride Cl^-*	- *Sodium chloride (NaCl)* - *Magnesium chloride $MgCl_2$* - *Aluminium chloride $AlCl_3$*
Acetic acid CH_3COOH	*Acetate CH_3COO^-*	- *Potassium acetate CH_3COOK* - *Copper acetate $(CH_3COO)_2Cu$* - *Iron acetate III $(CH_3COO)_3$ Fe*
Sulphuric acid H_2SO_4	*Sulphate $(SO_4)^{-2}$* *Bisulphate $(HSO_4)^-$*	- *Sodium sulphate Na_2SO_4* - *Sodium bisulphate $NaHSO_4$* - *Copper sulphate $CuSO_4$* - *Copper bisulphate $CuHSO_4$*
Carbonic acid H_2CO_3	*Carbonate (CO_3)* *Bicarbonate (HCO_3)*	- *Sodium carbonate Na_2CO_4* - *Sodium bicarbonate Na_2HCO_4* - *Calcium carbonate $CaCO_3$* - *Magnesium bicarbonate $Mg(HCO_3)_2$*

We notice from the previous table that:-

1- Some acids have two kinds of salts *because their molecules have 2 hydrogen atoms (dibasic acids)* , *Dibasic acids (such as sulphuric and carbonic acids) have two kinds of salts because the molecules of each of them have 2 hydrogen atoms.*

Tribasic acids (such as phosphoric acid) have three kinds of salts because their molecules contain 3 hydrogen atoms

2- The names of salts which contain hydrogen in their anions are called ***"bi____"*** ***"Hydrogen*** *______"*

→ *HSO_{4^-} can be called "**Bi**sulphate" or "**Hydrogen** sulphate"*

*3- Numbers II and III indicates the valency of the metal bound to the anion of the acid, (**Such numbers are written in cases of multivalent metals – metal having more than one valence such as iron)***

Remember

Valence: *The no. of electrons gained, given, or shared by atoms*
The valence of metals: *The no. of electrons that metal atoms lose during chemical reaction*
The valence of nonmetals: *The no. of electrons that nonmetal atoms gain during chemical reaction*

4- The acidic anion of salts is written on the right, while the basic cation is written on the left
→ *NaCl **(the basic cation in this salt is Na and written on the left, while the acidic anion is Cl and written on the right)***

*5- In the case of organic acids (such as acetic acid) the anion of acid is written on the left (such as Potassium acetate **CH_3COO**K)*

Solubility of salts

→ *Some salts dissolve quickly in water, some of them dissolve in hot or cold water. There are also salts that don't dissolve in water*

Salts	***Solubility of water***
- Salts of sodium, potassium and ammonium	*They dissolve in water*
- Nitrates	*They dissolve in water*
- Sulphates	*They dissolve in water (**except for calcium, barium, lead and silver sulphates)***
- Bicarbonates	*They dissolve in water*
- Carbonates	*They don't dissolve in water (**except for sodium, ammonia and potassium)***

- Chloride	They all dissolve in cold water - lead chloride ($PbCl_2$) dissolves in hot water - Mercury ($HgCl_2$) and silver chloride ($AgCl$) don't dissolve in water

Aqueous solutions of salts are different in their properties:-

→ *They may have acidic effect if the acid is strong and the base is weak such as* ***Ammonium chloride (NH_4Cl)***

→ *They may have basic effect if the acid is weak and the base is strong such as* ***sodium carbonate (Na_2CO_3)***

→ *They may be neutral if the strength of the acid and base are equal such as* ***Acetic acid (CH_3COOH)***

Definitions of lesson (2)

Arrhenius acid: *The substance which disassociate in water producing one or more positive hydrogen ions (H^+)*

Arrhenius base: *The substance which disassociate in water producing one or more negative hydroxide ions (OH^-)*

Bronsted-Lowry acid: *The substance that loses protons during chemical reaction (proton donor)*

Bronsted-Lowry base: *The substance that has the ability to gain protons (proton acceptor)*

Conjugate acid: *The substance formed when a base gains proton*

Conjugate base: *The substance formed when an acid loses proton*

Lewis acid: *The substance which gains one or more electrons*

Lewis base: *The substance which loses one or more electrons*

Indicators: *weak acids and bases whose colours change by the change of solution*

pH: *A method used for determining the acidity or basicity of a solution in numerical values ranging from 0 to 14*

Rationalize

1- There aren't any free protons in the aqueous solutions of acids
because they bond with water molecules forming hydronium ions (H_3O^+)

2- Ammonia is considered as a base although it doesn't have hydroxide groups in its structure

Because according to Lewis theory, ammonia accepts protons from water molecules forming hydronium ions.

3- Nitric acid is a strong acid

Because its molecules completely disassociate in water into ions, which gives its aqueous solutions the ability to conduct electricity efficiently

4- Acetic acid is a weak acid

Because some of its molecules disassociate in water into ions, which makes its aqueous solutions weak conductors of electricity.

5- Ethyl alcohol is nonelectrolyte

Because its molecules doesn't disassociate in water into ions and cannot conduct electricity.

6- Some acids such as carbonic acid have two types of salts

Because their molecules structure contain two hydrogen atoms (dibasic acids)

7- pH of ammonium chloride solution is less than 7

Because it has an acidic effect, as its formed from an anion of strong acid (chloride negative ion) and a cation of weak base (ammonium positive ion)

8- pH of sodium carbonate solution is more than 7

Because it has a basic effect, as it's formed from an anion of weak acid and a cation of strong base

9- pH of acetic acid equals 7

Because the strengths of the acid anion and base cation are equal

Exercise on lesson (2)

1- Choose the correct answer

1- Phosphoric acid H_3PO_4 is ……. acid

A- Monobasic B- Dibasic C- Tribasic B-Multibasic

2- The pH of an acidic solution is…..

A- 7 B- 5.5 C- 8.5 D-14

3- When ammonia reacts with hydrochloric acid, ammonium ion NH_4^+ is…

A- Conjuagte acid B- acid C- Base D- Conjugate base

4-…… is a strong acid

A- Acetic acid B- Carbonic acid C- Nitric acid D- Citric acid

5- The colour of phenolphthalein changes to fuchsia in a solution of ….. pH
A- 2 B-4 C-6 D-9

2- Write the scientific term

1- A substance that contains hydrogen and gives it away when reaction with metals

2- A chemical substance whose colour change by the change of the solution

3- A method for determining the type of solution in numerical values ranging from 0 to 14

4- A substance that has the ability to accept protons

5- A substance that gives away protons

3- Answer the following questions.

*1- Compare between the definitions of acid and bases in The Arrhenius, Bronsted-Lowry and Lewis theories (**with giving examples and chemical reactions**)*

2- Determine the basic cations and the acidic anions of the following salts:-
A- Potassium nitrate
B- Sodium acetate
C- Ammonium phosphate
D- Copper sulphate

The answers

1- Choose

1- Tribasic

2- 5.5

3- Conjugate base

*Ammonia (A Bronsted-Lowry base) reacts with hydrochloric acid (Bronsted-Lowry acid) forming ammonium ion (**A conjugate acid because it gains a proton***

4- Nitric acid

5- 9 (Base)

Write the scientific term

1- Acid

2- Indicator

3- pH

4- Bronsted-Lowry base

5- Bronsted-Lowry acid

Answer the following questions

1- Page 21

2-

Salt	***Acidic anion***	***Basic cation***
Potassium nitrate KNO_3	NO_3^{-}	K^{+}
Sodium acetate CH_3COONa	CH_3COO^{-}	Na^{+}
Ammonium phosphate $(NH_4)_3PO_4$	PO_4^{+3}	NH_4^{-}
Copper sulphate $CuSO_4$	SO_4^{--}	Cu^{++}

General test on chapter 3 (Without answers)

1- Choose the correct answer

1- In neutral medium, the indicator which has a purple colour is.......
A- Litmus paper B- Phenolphthalein C- Bromothymol blue D- Methyl orange

2- pH of an alkaline solution may equal....
A- 7 B- 8 C- 2 D-5

3- The colour of phenolphthalein in acidic medium...
A- Colourless B- Red C- Blue D- Purple

4- Acids react with carbonates or bicarbonates forming......gas
A- Hydrogen B- Nitrogen C-Carbon dioxide D- Oxygen

5- When dissolving 20g of NaOH in a quantity of water and the solution was completed to 250ml, The molar concentration will be... (Na=23, O=16, H=1)
A- 0.5 M B- 0.25 M C- 1 M D- 2M

6- All of the following are metal acids except for...
A- Carbonic acid B- Citric acid C- Hydrochloric acid D- Phosphoric acid

7- All of the following acids are strong except for…

A- HBr B- H_2CO_3 C- HNO_3 D- $HClO_4$

8- When dissolving ……. Salt in water, an acidic solution is formed

A- NaCl B- Na_2CO_3 C- NH_4Cl D- CH_3COONa

9- ……… salt produces an acidic solution when dissolving in water

A- NH_4Cl B- $NaNO_3$ C- K_2CO_3 D- KCl

10- if one mole of one the following compounds dissolved in 1L of water, which of them has the greatest effect on vapour pressure?

A- KBr B- $MgCl_2$ C- $CaSO_4$ D- $C_6H_{12}O_6$

2- Correct the underlined words

1- The colour of phenolphthalein changes to red (fuchsia) in neutral solutions

2- Carbonic acid H_2CO_3 is a tribasic acid

3- Citric acid is a dibasic acid

4- According to the Arrhenius theory, acid is the substance which dissolve in water producing OH^- ion

5- Solutions of pH = 7 are acidic

6- Dilute acids react with active metals producing oxygen gas

7- A solution is neutral if its pH is greater than 7

8- The molality (m) of a solution containing 0.5 M of solute and 500g of solvent is 2 mol/kg

3- Write the scientific term

1- Substances that react with bases forming water and salt

2- Substances that dissolve in water producing positive hydrogen ions

3- A substance which has a sour taste and changes the colour of red litmus paper into blue

4- A substance formed when a base gains a proton

5- A weak acid or base whose colour change by the change of solution

6- A substance formed when an acid loses a proton

7- The no. of moles dissolved in one litre of an aqueous solution

8- The no. of moles dissolved in one kilogram of solvent

9- The mass of solute in 100g of solvent at a certain temperature

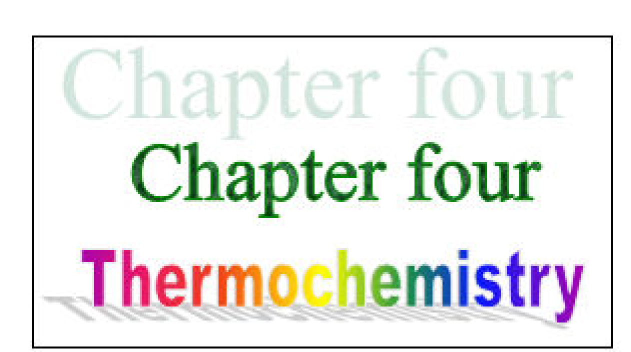
3- Answer the following questions

1- write the balanced chemical equations for the following reactions :-

A – Sulphuric acid with zinc

B- Nitric acid in an aqueous solution of sodium hydroxide

2- KI and $MgCl_2$ salts were dissolved in equal volumes of water with equal no. of moles forming two solutions, which solution has higher boiling point? why?



Lesson (1) Heat content

Lesson (2) Forms of change in heat contents

Lesson (1) Heat content



Thermochemistry: *One of the branches of thermodynamics which studies thermal changes which associate with chemical and physical transformations*

Law of conservation of energy

Law of conservation of energy: *Energy can be neither created nor destroyed, but can change from one form to another.*

Chemical reactions are associated with changes in energy. They may absorb or give off energy. Energy is exchanged between the medium of the reaction (called the system) and the surrounding medium (called surrounding)

System: *A part of the universe in which chemical or physical changes occur **or** the certain part of matter which is studied.*

Surrounding: *The region surrounding the system which exchanges energy with it in the form of heat or work*

System and surrounding of chemical reactions:-
System → *beakers, flasks or test tubes in which chemical reactions occur*
Surrounding → *Anything around the medium of chemical reactions.*

Types of systems

Isolated system: *It doesn't allow the exchange of matter or energy between the system and surrounding.*
→ *Example: Water in an isolated container.*

Opened system: *It allows the exchange of both energy and matter between the system and surrounding.*
→ *Example: Water in an open sea*

Closed system: *It allows the exchange of **energy only** between the system and surrounding in the form of heat or work*
→ *Example: Thermometer*

First law of thermodynamics

First law of thermodynamics: *The total energy of isolated systems remains constant, even if the form of the system changed.*

Explanation:-

We know that universe = system + surrounding

Therefore:-

change of universe energy = change of system energy + change of surrounding energy

$$\Delta E_{\text{universe}} = \Delta E_{\text{system}} + \Delta E_{\text{surrounding}}$$

Therefore, any change occurs to the energy of the system is associated with an equivalent change in that of the surrounding, but with different sign to keep the total energy constant.

$$\Delta E_{\text{system}} = - \Delta E_{\text{surrounding}}$$

Heat and temperature

Temperature: *The measurement of the average kinetic energy of the molecules of substance, which determines if it is hot or cold.*

System → *The group of molecules which react with each other. When the average kinetic energy of the molecules of a substance increases, the temperature increases.*

Heat: *A form of energy which is transferred between two objects of different temperatures*

→ *The energy of a system is directly proportional to the kinetic energy of its particle.*

Measuring units of heat

Calorie (cal): *The amount of heat required to raise the temperature of 1g of water 1◦C*

Joule (J): *The amount of heat required the raise the temperature of 1g of water* $\frac{1}{4.184}$ ◦C

(N.B: *1 joule = 4.184 calories)*

Specific heat

Specific heat: *The amount of heat required to raise the temperature of 1g of matter 1◦C*

→ ***Measuring unit of specific heat =*** *J / g◦C or J / g◦K*

Specific heats depends on the kind of substance, as the specific heat is high in substances which require great amounts of heat to raise their temperatures, and they take much time to lose heat. And the opposite to substances with low specific heat.
*(**N.B:** water has the greatest specific heat on the surface of the earth)*

Substance	Aluminium	Carbon	Copper	Iron	Liquid water	Water vapour
Specific heat	0.9	0.711	0.385	0.444	4.184	2.01

<u>Calculation of heat amount law</u>

$$q = m \times c \times \Delta T$$

q = The amount of heat at certain pressure
m = mass
c = specific heat
ΔT = The difference between final temperature T_2 (temperature after heating) and initial temperature T_1 (temperature before heating)

$$\Delta T = T_2 - T_1$$

→ *Heat capacity (C) = m x c*
→ *Amount of heat is measured by a device called "Calorimeter"*

Calorimeter

Function: *It measures the heat of chemical reaction of physical changes.*

It provides us with an isolated system whose temperature can be calculated. It doesn't allow the exchange of energy and matter between the system and surrounding.
This enables us to use a certain amount of substance with which thermal exchange occurs. Water is used usually because it has high specific heat which allows it gain and lose great amount of energy. Then, we calculate the change of temperature by the following law:-

$$\Delta T = T_2 - T_1$$

ΔT = Change of temperature.

T_1 = Initial temperature (temperature before heating)

T_2 = Final temperature (temperature after heating)

Components of calorimeter:-

1- Isolated vessel

2- Thermometer

3- Stirrer

4- A liquid (usually water)

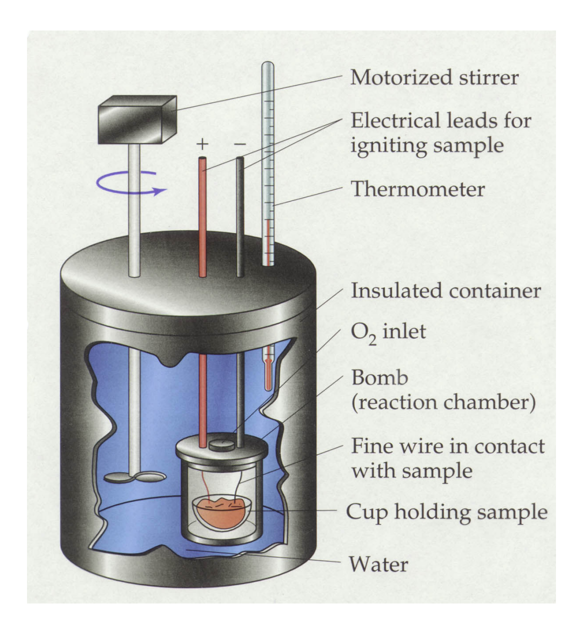


Fig. (1) Structure of calorimeter

<u>Combustion calorimeter</u>

Function: *Measure the heat of combustion of some substances.*

Idea of operation:-

We burn certain amounts of the substance (by using an electric wire) in oxygen gas at constant atomic pressure in a vessel called "Decomposition vessel". Decomposition vessel is surrounded by a certain amount of water.



Fig. (2) Combustion calorimeter

Example (1)

When using a calorimeter, 0.28g of propanol fuel was burned, which raised the temperature of water 21.5◦C (the mass of water in calorimeter equals 100g) Find the amount of energy resulted from burning the fuel.

Solution:-

The mass of water (m) = 100g
The change of temperature (ΔT) = 21.5◦C
The specific heat of water (c) = 4.184 j/g◦C

The amount of heat = m x c x ΔT = 100 x 4.184 x 21.5 = 9030 Joules

Heat capacity

Heat capacity: *The quantiy of heat required to raise the temperature of an object 1◦C.*

→ *Measuring unit of heat capacity is J / ◦C*

Factors affecting heat capacity

- The mass of the object:-
The heat capacity of water in basin is greater than that of water in a cup or glass

- The kind of the substance:-
The heat capacity differs from one substances to another, even if they are equal in mass.

Example

When dissolving sodium nitrates in a quantity of water, and this quantity was raised to 100ml, the temperature of the solution decreased from 25◦C to 17◦C. Calculate the quantity of absorbed energy

Solution:-

In dilute solutions, the mass of one milliliter of water equals 1g, therefore, the mass of 100ml of water is 100g

Mass of water (m) = 100g
Specific heat (c) = 4.18
The change of temperature (ΔT) = 25-17 = 8◦C

The amount of absorbed energy (q) = m x c x ΔT = 100x 4.18 x 8 = 3334 J/mol
(N.B: kilo joule (kJ) = 1000 joules)
The amount of energy = 3.334 J/mol

Heat content

Every substance has energy stored in it, this energy is known as "Internal energy"

Chemical energy stored in the atom: *The energy of electrons in their levels, which is the sum of the potential and kinetic energies of the electron in its level.*

Chemical energy stored in molecule: *It exists in the chemical bonds between its atoms (covalent, ionic bonds)*

Molecules binding forces: *The attraction force between molecules is known as "Van der waal force" which is a potential energy.*

→ *There are many other forces between molecules such as Hydrogen bonds, these forces depend on the nature and polarity of molecules.*

We conclude from the previous remarks that each substance has a great amount of stored energy, which is known as "Heat content" or "Molar enthalpy"

Heat content (molar enthalpy): *The sum of energies stored in one mole of matter*

→ *Substances have different heat contents due to the difference of the number of atoms, their kinds and the bonds between them.*

→ *We cannot measure the heat content of a substance practically, but we can calculate the change in heat content which occurs due of the different transformations of the substance*

Change in heat content (ΔH): *The difference between the total heat content of products and that of reactants in a chemical reaction.*

The change in heat content = heat content of products + heat content of reactants

$$\Delta H = H_{products} - H_{reactants}$$

The change in standard heat content (ΔH°)

Change in heat contents are calculated in standard conditions which are:-

- *Pressure = 1 atomic pressure (1 atm)*
- *Temperature = 25°C*
- *Concentration of solution = 1 mole*

The heat content of an element = zero

We calculate the change in heat content by the following law:-

$$\Delta H = q_p / n$$

ΔH = *change in heat content*
q_p = *Heat amount*
n = *number of moles*

We can divide chemical reactions which associate change in temperature into:-

First: Exothermic reactions

They are reactions which give off energy as a product to the surrounding, which increases its temperature.

Example

The reaction of one mole of hydrogen gas with half mole of oxygen gas forms one mole of water and heat of 285.5kJ/mol

$$H_{2\,(g)} + 1/2\ O_{2\,(g)} \rightarrow H_2O_{\,(l)} + 285.5 kJ/mol$$

From the previous reaction, we conclude that:-

1- Heat transfers from the system to the surrounding, which decreases the temp. of the system and increases that of the surrounding.

2- The total heat content of products is less than that of reactants. Thus, the reaction gives off energy to achieve the conservation law of energy.

→ *In exothermic reactions, we describe the change in heat content (ΔH) by negative sign ($-\Delta H$)*

First: Endothermic reactions

Reactions in which energy is absorbed from the surrounding, which decreases its temperature.

Example:-

When one mole of magnesium carbonates decomposes into carbon dioxide gas and magnesium oxide, it needs to absorb energy of 117.3kJ/mol.

$$MgCO_{3\,(s)} + 117.3\ kJ/mol \rightarrow MgO_{\,(s)} + CO_{2\,(g)}$$

From the previous reaction, we conclude that:-

1- Heat transfers from the surrounding to the system, so the system gains energy while the surrounding loses it.

2- The total heat content of products is greater than that of reactants. Thus, reaction absorbs energy to achieve the conservation law of energy.

→ *In endothermic reactions, we describe the change in heat content by positive sign (+ΔH)*

- In endothermic reactions, the change in heat content is positive (+ ΔH)
- In exothermic reactions, the change in heat content is negative (- ΔH)

Bond energy and heat content

During chemical reactions, the bonds of reactants break up to form new bonds in the products.
→ *When a bond breaks up, it absorbs an amount of energy from the surrounding.*
→ *When a new bond is formed, it gives away an amount of energy to the surrounding (which increases its temperature)*

Bond energy: *The energy required to break the bonds between molecules in one mole of matter*

Bond	Average bond energy (kJ / mol)
H – H	432
C – O	358
C = O	745
O – H	467
O = O	498
C – C	346
C = C	610
C ≡ C	835
C – H	413
Si – H	318

Energies of some bonds

→ *In exothermic reactions (- ΔH◦) the energy released from forming new bonds in product molecules is greater than that formed from breaking up the bonds in reactant molecules.*

→ *In endothermic reactions (+ ΔH◦) the energy absorbed by reactant molecules to break up their bonds is greater that the energy released from forming new bonds in the products.*

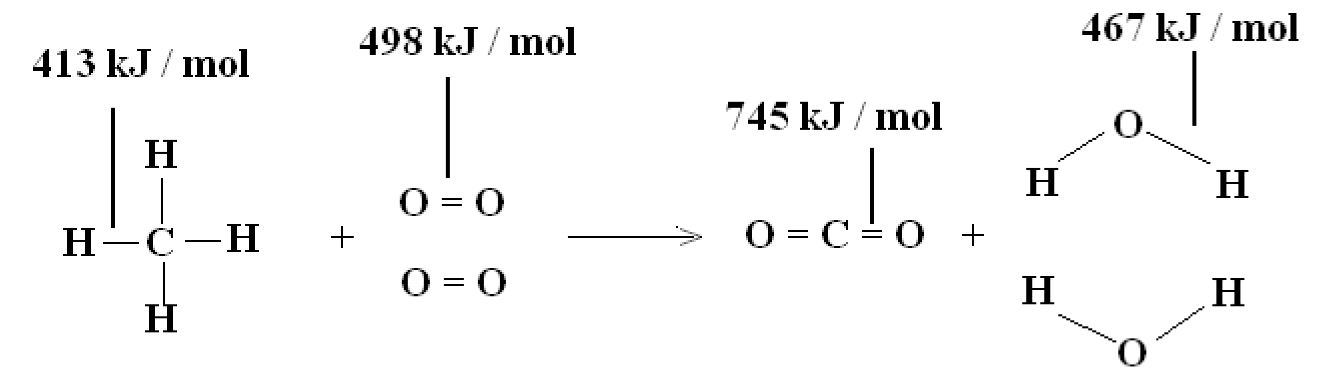
Example

Calculate the heat of the following reactions, and find if it its exothermic or endothermic.

$$CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{(g)}$$

(O=O) 498, (C-H) 413, (O-H) 467, (C = O) 745

Solution:-



The energy required to break up the reactant molecules =
[4 x (C – H)] + [2 x (O = O)] = [4 x 413] + [2 x 498] = 2648 kJ

The energy released from forming the product molecules =
[2 x (C=O)] + [4 x (O – H)] = [2 x 745] + [4 x 467] = 3358 kJ

$\Delta H = H_{products} - H_{reactants} = 3358 - 2648 = +710$ *kJ / mol.*

The change in heat content is positive, therefore the reaction is endothermic.

Thermochemical equation

Thermochemical equation: *A balanced chemical equation which includes the thermal (enthalpy) change associated with the reaction as one of the reaction products or reactants.*

Conditions of thermochemical reactions

1- it should be balanced, and the numbers which are written before the products and reactants formulas describe the no. of moles (not the no. of molecules). Therefore, in thermochemical reactions, we can write theses numbers in the form of fractions. For example:-

$$H_{2\,(g)} + 1/2\ O_{2\,(g)} \rightarrow H_2O_{(l)} + 285.5 \text{ kJ / mol.}$$

2- The physical state of the reactants and products should be mentioned (s), (l),(g), (aq) because the heat content change by the change of physical state, for example:-

$$H_{2\,(g)} + 1/2\ O_{2\,(g)} \rightarrow H_2O_{(l)} + 285.5\ kJ / mol.\ \text{(water in liquid state)}$$
$$H_{2\,(g)} + 1/2\ O_{2\,(g)} \rightarrow H_2O_{(g)} + 242\ kJ / mol.\ \text{(water in gaseous state)}$$

3- The value and sign of heat content is mentioned to determine whether the reaction is endothermic or exothermic.

$$H_2O_{(s)} \rightarrow H_2O_{(l)} \quad \Delta H^\circ = +\ 6\ kJ / mol\ \ \text{(endothermic reaction)}$$

4- When multiplying the sides of thermochemical equations, we shouldn't forget to multiply the amount of heat.

$$H_2O_{(s)} \rightarrow H_2O_{(l)} \qquad \Delta H^\circ = +\ 6\ kJ / mol$$
$$2H_2O_{(s)} \rightarrow 2H_2O_{(l)} \quad \Delta H^\circ = \ 2 \times 6 = 12\ kJ / mol.$$

Change in heat content and reactivity

Most reactions which occur in nature are exothermic reactions. In these reactions, the energy of the products is less than that of the reactants because energy gets released when they react together.

It was believed that endothermic reactions couldn't occur spontaneously (automatically) because they require certain conditions (heating). But scientists discovered that endothermic reactions can occur spontaneously.

→ Therefore, we conclude that there is something which controls the spontaneous (automatic) occurrence of chemical reactions, which is called entropy.

Entropy:-

→ Melting process is an example on endothermic reactions which occur spontaneously in nature. A cube of ice melts down to water because energy transfers from air to ice.

$$H_2O_{(s)}\ +\ 6\ kJ / mol \rightarrow H_2O_{(l)}$$

This endothermic reaction occurred spontaneously although the energy of the reactants is lower that that of products. Thus, there's a factor which determines the spontaneous occurrence of chemical reactions which has a relation with arrangement degree. This factor is known as entropy

***Entropy:** The measure of randomness (disorder) level in a certain system*

Law of disorder (randomness): *Changes occur in the way which increases disorder (randomness) - reactions occur in the way which increases entropy*

→ *Changes occur in the way which decreases energy.*

→ *in the previous example, water molecules in ice crystal lose their ordered arrangement. Thus, they change to liquid state (which is less ordered and has higher heat content)*

Free energy

Free energy: *The ability to do work*

→ *Chemical reactions occur in the way which decreases the system energy and increases the entropy (randomness) in the system.*

→ *In order to know which one of the previous factors prevails on the other. We used a function which describe the relation between the change in heat content and the change in entropy, This function is known as free energy.*

The following table describes the relation between the spontaneous occurrence of a reaction, the change in heat content, and the change in entropy

Change in heat content	**Change in entropy**	**Spontaneity of reaction**
Negative (exothermic)	Positive (more random)	Always spontaneous
Negative (exothermic)	Negative (less random)	Rarely spontaneous
Positive (endothermic)	Positive (more random)	More spontaneous
Positive (endothermic)	Negative (less random)	Non spontaneous

Definitions of lesson (1)

Thermochemistry: *One of the branches of thermodynamics which studies thermal changes associated with chemical and physical transformations.*

System: *A part of the universe in which chemical or physical changes occur* ***or*** *the certain part of matter which we study*

Surrounding: *The region surrounding the system which exchanges energy with it in the form of heat or work.*

Conservation law of energy: *Energy can be neither created nor destroyed, but can change from one form to another.*

First law of thermodynamics: *The total energy of any isolated systems remains constant, even if the form of the system changed.*

Temperature: *The measurement of the average kinetic energy of the molecules of substance, which determines if it is hot or cold.*

Heat: *Form of energy which is transferred between two objects of different temperatures*

Specific heat: *The amount of heat required to raise the temperature of 1g of matter 1◦C*

Calorie (cal): *The amount of heat required to raise the temperature of 1g of water 1◦C*

Joule (J): *The amount of heat required the raise the temperature of 1g of water 1/4.184 ◦C*

Heat capacity: *The amount of heat required to raise the temperature of an object 1◦C*

Heat content (molar enthalpy): *The sum of energies stored in one mole of matter*

Change in heat content (ΔH): *The difference between the total heat content of products and that of reactants in a chemical reaction.*

Bond energy: *The energy required to break the bonds between molecules in one mole of matter.*

Thermochemical equation: *A balanced chemical equation which includes the thermal (enthalpy) change associated with the reaction (as one of the reaction products or reactants)*

Entropy: *The measure of randomness (disorder) level in a certain system.*
Law of disorder (randomness): *Changes occur in the way which increases disorder (randomness) - reactions occur in the way which increases entropy -*

Free energy: *The ability to do work.*

Give scientific reasons for

1- Thermometer is an example of closed system
Because it allows the transfer of energy between the surrounding and system, which gives it the ability to measure temperatures. But it doesn't allow the transfer of mass.

2- water in an open sea is an example of open system
Because it allows the transfer of both energy and mass (water vapour) between the system (the sea) and the surrounding (anything around the sea).

3- Water plays an important role in climate on the surface of the earth.
Because the high specific heat of water enables it to absorb great amounts of energy and lose them in much time, which makes the climate of earth suitable for life in winter and summer, in the morning and at night.

4- Dissolution of potassium iodide in water is an exothermic reaction.
Because the change of heat content ΔH° has a negative sign, as the heat content of the reactants is greater than that of products. Thus, the difference of energy is released with the reactants.

Questions

1- Choose the correct answer

1- The measuring unit of specific heat is ………
A- Joule   B- J/mol   C- J/g   D- J / g°C

2- Which one of the following substances has the greatest specific heat
A- 1g of water   B- 1g of iron   C- 1g of aluminium D- 1g of mercury

3- In exothermic reactions, …
A- Heat transfers from the surrounding to system
B- Heat transfers from the system to the surrounding
C- Heat doesn't transfer between the system and surrounding
D- Heat transfers between the system and surrounding at the same time.

4- In isolated system,…..
A- heat and mass are exchanged between the system and surrounding
B- heat is exchanged between the system and surrounding.
C- Mass is exchanged between the system and surrounding
D- Neither mass nor heat are exchanged between the system and surrounding

5- The standard conditions for reaction are ….
A- pressure 1 atm and temperature 0°C
B- Pressure 1 atm and temperature 25°C
C- Pressure 1 atm and temperature 50°C
D- Pressure 1 atm and temperature 100°C

2- What is the meaning of

1- Heat capacity of an object = 1000 J/°C
2- Specific heat of water = 4.18 J/g°C

3- Write the scientific term

1- The amount of heat required to increase the temperature of an object one degree Celsius

2- Chemical equation which includes thermal changes associated with the reaction.

4- Correct the underlined words

1- Specific heat is <u>constant</u> in all substances

2- c= <u>q / v x ΔT</u>

3- Heat capacity depends on the <u>volume</u> of object

4- Chemical energy in <u>molecule</u> is resulted from the energy level, which is the sum of the potential and kinetic energies of the electron.

5- <u>Heat capacity</u> is the sum of the energies stored in one mole of matter.

5- The specific heat of platinium = 0.133 J/g◦C, titanium = 0.528 J/g◦C, zinc = 0.388 J/g◦C. If we have samples of the previous metals of mass 70g each at the ordinary temperature of room. Which of the previous metals its temperature will increase before the others ? why?

6- How does the process of breaking down reactants bonds and forming products bonds determine if a reaction is endothermic or exothermic?

7- Find the final temperature of 4.5g of gold particles which absorbed 276 Joules of energy when they were heated, the initial temp. was 25◦C and specific heat of gold equals 0.13 J/g

8- An unknown substance of mass 155g absorbed 5700J of energy, which increases its temp. form 25◦C to 40◦C. Calculate its specific heat

9- Calculate the amount of heat released from cooling down 350g of mercury from 77◦C to 12◦C. The specific heat of mercury = 0.14 J/g◦C

10- Calculate the specific heat of 360g of silver whose heat capacity equals 86J/g

Solutions

1- Choose

1- J / g◦C
2- 1g of water
3- Heat transfers from the system to the surrounding
4- Neither mass nor heat are exchanged between the system and surrounding
5- Pressure 1 atm and temperature 25◦C

2- What is the meaning of

1- It means that the amount of energy required to raise the temp. of this object 1 degree Celsius equals 1000 joules

2- It means that the amount of heat required to increase the temperature of 1 gram of water 1 degree Celsius equals 4.18 joules

3- Write the scientific term

1- Heat capacity
2- Thermochemical equation

4- Correct the underlined word

1- Different
2- $q / m \times \Delta T$
3- Mass
4- atom
5- Heat content

Question (5)

Platinium metal temperature increases before the other metals because it has the least specific heat, which allows it to absorb more energy.

Question (6)

If the energy resulted from breaking down reactant molecules is greater than that resulted from forming new bonds in the products , this reaction is exothermic (gives off energy). On the other hand, if the energy resulted from forming new bonds in products is greater than that resulted from breaking down reactant molecules, the reaction is endothermic (absorbs energy)

Question (7)

$$q = c.\ m.\ \Delta T$$

q (amount of energy) = 276 joules
c (specific heat) = 0.13 J/g
m (mass) = 4.5g
, $\Delta T = q / (c.m) = 276 / (0.13 \times 4.5) = 471.8^{\circ}$ C

$$\Delta T = T_2 - T_1$$

$\Delta T = 471.8^{\circ}C$
T_1 (initial temperature) = $25^{\circ}C$
T_2 (final temperature) = $471.8 + 25 = 496.8^{\circ}C$

Question (8)

$$q = c.\ m.\ \Delta T$$

q (energy) = 5700 J
m (mass) = 155g
$\Delta T = 40 - 25 = 15^{\circ}C$
Specific heat (c) = $q / (m.\ \Delta T) = 5700 / (155 \times 15) = 2.45$ J/g$^{\circ}$C

Question (9)

$$q = c.\ m.\ \Delta T$$

c (specific heat) = 0.14 J/g$^{\circ}$C
m (mass) = 350g
$\Delta T = 77 - 12 = 65^{\circ}C$
The amount of energy (q) = $0.14 \times 350 \times 65 = 3185$ Joules

Question (10)

$$C = c.\ m$$

Heat capacity (C) = c.m = 86 J/g
Mass (m) = 860g
Specific heat (c) = m / C = 860/86 = 10 J/g$^{\circ}$C

Lesson (2) Forms of change in heat content



Calculating heat content associated with the combustion of different types of fuel is very important because:-

- It helps firefighters determine the amount of heat accompanied with combustion.

- It helps them also choose the best methods to put out fire

Thermal changes accompanied with physical transformations

→ *Examples: Dissolution – Dilution – Change in physical state*

Standard heat of solution

Standard heat of solution ($\Delta H_s°$): *The amount of heat released or absorbed when dissolving one mole of solute in a certain quantity of solvent to get a saturated solution in standard conditions*

Endothermic solution process:-

When dissolving one mole of ammonium nitrate (NH_4NO_3) in water, the temperature of the solution decreases, which is known as endothermic solution

$$NH_4NO_{3\,(s)} \xrightarrow{H_2O} NH_4{}^+{}_{(aq)} + NO_3{}^-{}_{(aq)} \qquad \Delta H_s° = +25.7\ kJ/mol$$

Exothermic solution process:-

When dissolving one mole of NaOH in water, the temperature of the solution increases, which is known as exothermic dissolution.

$$NaOH_{(s)} \xrightarrow{H_2O} Na^+{}_{(aq)} + OH^-{}_{(aq)} \qquad \Delta H_s° = -51\ kJ/mol$$

Explanation of standard heat of dissolution

1- Separating between the molecules of solvent: An endothermic process which absorbs energy to overcome the attraction forces between the solvent molecules, denoted by ΔH_1

2- Separating between the molecules of solute: An endothermic process which absorbs energy to overcome the attraction forces between the particles of solvent, denoted by ΔH_2

3- Dissolution process: An exothermic process which gives off energy because solute molecules bind to solvent ones, denoted by ΔH_3

If $\Delta H_1 + \Delta H_2 > \Delta H_3$, solution will be endothermic

If $\Delta H_1 + \Delta H_2 < \Delta H_3$, solution will be exothermic

To calculate the standard heat of solution, we use the following law:-

$$q = m.\ c.\ \Delta T$$

In diluted solutions, their masses are equal to their volumes because the density of water equals 1g/mol
We use the specific heat of water (4.18 J/g◦C).

***Molar heat of solution:** Thermal change resulted from the dissolution of one mole of solute in solvent forming one liter of solution*

Standard heat of dilution

***Standard heat of dilution ΔH_{dil}° :** The amount of heat absorbed or released per every mole of solute when decreasing the concentration of solution in standard conditions*

In high-concentrated solutions, the ions of the solvent are very close to each other, but when we decrease their concentrations by adding more quantity of solvent, ions pull away from each other, which absorbs energy. When the no. of solvent molecules increases, ions bind to more molecules, which releases energy.

Thermal changes associated with chemical transformations

Standard heat of combustion

Combustion is a sequence of exothermic chemical reactions between matter and oxygen. Complete combustion of substances release a great quantity of energy in the form of heat or light. This released energy is known as "heat of combustion ΔH_c"

***Standard heat of combustion ΔH_c°:** The amount of energy released from the complete combustion of one mole of matter in standard conditions.*

Examples of combustion reactions:-

1- Combustion of natural gas (mixture of Butane C_4H_{10} and propane C_3H_8) in oxygen of air releases great quantity of energy, which is used in cooking at home

$$C_3H_{8\,(g)} + 5O_{2\,(g)} \rightarrow 3CO_{2\,(g)} + 4H_2O_{(g)} + 2323.7\ kJ/\ mol$$

2- Combustion of Glucose ($C_6H_{12}O_6$) with oxygen inside living organisms, which supplies living organisms with energy required to carry out vital processes.

$$C_6H_{12}O_{6\,(s)} + 6O_{2\,(g)} \rightarrow 6CO_{2\,(g)} + 6H_2O \qquad \Delta H_c^{\circ} = -2808\ kJ/mol$$

Standard heat of formation

Standard heat of formation ΔH_F° *: The quantity of heat absorbed of released when forming one mole from its elements, its elements should be in standard conditions*

Heat of formation and the stability of compounds

Heat of formation: *Heat content of a compound*

→ Compounds which have negative heat content are more stable at the ordinary temperature of the room, and don't tend to decompose because their heat contents are low

→ Compounds which have positive heat contents are less stable at the ordinary temperature of room, and tend to decompose spontaneously into their elements.

(N.B: *Most chemical reactions occur in the way which makes compounds more stable)*

Using standard heat of formation in calculating change in heat content

Formation heat of an element equals zero in the following conditions:-

- Pressure of 1 atm

- Temperature of 25°C

We studied in the previous lesson that:-

$$\Delta H^\circ = H_{products} - H_{reactants.}$$

In this lesson, we can calculate ΔH° *of compounds using* ΔH_F° *by the following law:-*

ΔH = Sum of heat of formations of product – Sum of heat of formation of reactants

Example:-

Heat of formation of methane = - 74.6 kJ / mol , Carbon dioxide gas = - 393.5 kJ / mol , water vapour -241.8 kJ / mol. Calculate the change in heat content of the following reaction:-

$$CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{(g)}$$

Solution:-

ΔH = Sum of heat of formations of product – Sum of heat of formation of reactants =

$(CH_4 + 2O_2) – (CO_2 + 2H_2O) = [-74.6 + (2x0)] + [-393.5 + (2x -241.8)]$

$= 802.5$ *kJ / mol.*

Hess's Law

Scientists use indirect methods to calculate the heat of a reaction because:-

- Products and reactants may be mixed with other substances
- Some reactions take long time to occur (Ex. Rusting of iron)
- It may be dangerous to measure the heat of reaction practically
- It is hard to measure the heat of some reactions in standard conditions for heat and pressure

→ Scientists use "Hess's law" to measure the heat of such reactions

Hess's law: *Heat of reaction has a constant value which doesn't change in standard conditions, even if the reaction took place in one or more steps.*

Mathematical formula of Hess's law: $\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3 + \ldots$

Importance of Hess's law **:** *We can use it to measure the change in heat content of reactions indirectly, using other reactions with known heat contents.*

Example:-
Graphite and diamond are two forms of carbon. It is to hard to measure the heat content resulted from changing diamond into graphite because the reaction is very slow, but their heat of combustions are known. By using Hess's law, we can measure the heat content of the reaction as the following:-.



Fig. (3) Graphite



Fig. (4) Diamond

1) $C_{(s,graphite)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H^\circ = -393.5$ kJ / mol.
2) $C_{(s,diamond)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H^\circ = -395.4$ kJ / mol

By reversing equation (1), we get equation (3)
3) $CO_{2(g)} \rightarrow C_{(s,\ graphite)} + O_{2(g)}$ $\Delta H^\circ = 393.5$ kJ / mol

(N.B: When reversing equations, do not forget to change the sign of heat content)

By adding equation (2) and (3) and simplifying them
$C_{(s,diamond)} + O_{2(g)} \rightarrow CO_{2(g)} \rightarrow C_{(s,\ graphite)} + O_{2(g)}$

Heat content of the reaction = heat content of reaction (2) + heat content of reaction (3) = -395.4 + 393.5 = -1.9 kJ / mol

Definitions of lesson (2)

Standard heat of solution (ΔH_s °): *The amount of heat released or absorbed when dissolving one mole of solute in a certain quantity of solvent to get a saturated solution in standard conditions.*

Molar heat of solution: *Thermal change resulted from the dissolution of one mole of solute in solvent forming one liter of solution.*

Standard heat of dilution ΔH_{dil}° : *The amount of heat absorbed or released per every mole of solute when decreasing the concentration of solution (in case it is in its standard conditions.*

Standard heat of combustion ΔH_c°: *The amount of energy released from the complete combustion of one mole of matter in standard conditions.*

Standard heat of formation ΔH_F° : *The amount of heat absorbed of released when forming one mole from its elements, its elements should be in standard condition.*

Hess's law: *Heat of reaction has a constant value which doesn't change in standard conditions, even if the reaction took place in one or more steps.*

Give reasons for

1- Exothermic reactions form thermally stable products
Because exothermic reactions give off energy, which increases the stability of products, as compounds with less heat content are more stable.

2- Solution process is associated with thermal change.
Because dissolution process causes the separation of solvent molecules (which absorbs energy -endothermic-), the separation of solute molecules (which also absorbs energy – endothermic-) and dissolution process (which gives off energy – exothermic) which is the linkage of solute ions to solvent.

3- Dilution process is accompanied with release of energy
Because when we dissolve a quantity of solute in solvent, this makes the ions of solvent pull away from each other, which absorbs energy. When we increase the no. of solute molecules, ions bind to more molecules which gives off energy. These two processes cause change in heat content and release of energy

4- Heats of formation of compounds play an important role in their stability
Because compounds with low heat of formation (low heat content) are more stable and don't tend to decompose, whereas compounds with high heat of formation (high heat content) are less stable and tends to decompose to achieve stability.

5- Scientists use indirect methods to measure the heat of reaction
Because:-
- Products and reactants may be mixed with other substances
- Some reactions take long time to occur (Ex. Rusting of iron)
- It may be dangerous to measure the heat of reaction practically
- It is hard to measure the heat of some reactions in standard conditions for heat and pressure

6- Burning glucose inside living organisms is one of the most important combustion reactions.
Because living organisms burn glucose in oxygen gas, which forms carbon dioxide and water, and gives off energy which is important to carry out vital processes.

$$C_6H_{12}O_{6\,(s)} + 6O_{2\,(g)} \rightarrow 6CO_{2\,(g)} + 6H_2O \qquad \Delta H_c^\circ = -2808\ kJ/mol$$

7- Hess's law is a form of the first law of thermodynamics
Because Hess's law states that reaction has constant heat which doesn't change in standard conditions, and the first law of thermodynamics also states that the total energy of isolated systems remains constant, even if the form of the system changed.

8- Hess's law is used to measure the heat of formation of carbon monoxide.
To know the heat of formation of carbon monoxide indirectly using reactions with known heat of formation.

Notes

→ Breaking up bonds is an endothermic process (because it absorbs energy)
→ Forming new bonds is an exothermic process (because it gives off energy)
→ We change the sign of change in heat content in thermochemical equations when we reverse them.

Questions

1- Write the scientific term

1- The amount of heat released or absorbed when dissolving one mole of solute in a certain quantity of solvent to get a saturated solution in standard conditions.

2- The linkage of disassociated ions with water molecules.

3- The amount of heat absorbed or released per every mole of solute when decreasing the concentration of solution (in case it is in its standard conditions.

4- The amount of heat absorbed of released when forming one mole from its elements.

5- Heat of reaction has a constant value which doesn't change in standard conditions, even if the reaction took place in one or more steps.

Question (2)

Hydrogen gas is used as a fuel for space rockets because when it burns in oxygen, it releases a huge quantity of energy, its combustion reaction is:-

$$2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{\,(g)} \qquad \Delta H = -484 \text{ kJ/mol}$$

Find the amount of energy released from burning 1g of hydrogen gas.

Question (3)

Calculate the standard change in heat content of the following reaction:-

$$H_2S_{\,(g)} + 4F_{2\,(g)} \rightarrow 2HF_{\,(g)} + SF_{6\,(g)}$$

H_2S = - 21 kJ/mol, HF = -273 kJ/mol, SF_6 = -1220 kJ/mol

Question (4)

When dissolving one mole of ammonium nitrate in water, and we completed the solution to 1000ml, the solution temperature decreased by 6°C. Calculate the amount of absorbed energy.

*(**N.B:** The specific heat of solution = 4.18 J/g°C , the density of solution = 1g/ml)*

Question (5)

The change in heat content of octane (C_8H_{18}) = -1367 kJ / mol. Write the chemical equation which describes the combustion of one mole of octane in oxygen completely.

(N.B: the products of the reaction are water and carbon dioxide gas)

(C=12, O=16, H=1)

Question (6)

If nitric oxide (NO) gas burned forming nitric dioxide gas (NO_2), as in the following:-

$$NO + 1/2\ O_{2\,(g)} \rightarrow NO_{2\,(g)}$$

Calculate the change in heat content of the previous equation using the following two equations:-

$$(1)\ 1/2\ N_{2\,(g)} + 1/2\ O_{2\,(g)} \rightarrow NO_{(g)} \qquad \Delta H = +90.29\ kJ/mol$$

$$(2)\ 1/2\ N_{2\,(g)} + O_{2\,(g)} \rightarrow NO_{2\,(g)} \qquad \Delta H = +33.2\ kJ/mol$$

Question (7)

Calculate ΔH of dissolving 80g of sodium nitrate in water to form 1 liter of solution, the initial temp. was 20 degree and decreased to 14 after the reaction.

Question (8)

If the heat of combustion of ethanol (C_2H_5OH) is 1367 kJ/mol, write the chemical reaction which describe the combustion of ethanol in oxygen forming water and carbon dioxide gas. Then calculate the amount of heat resulted from the combustion of 100g of ethanol

(C=12, O=16, H=1)

Solution

1- Write the scientific term

1- Standard heat of solution
2- Dissolution process
3- Standard heat of dilution
4- Standard heat of formation
5- Hess's law

Question (2)

The combustion of two moles of hydrogen in oxygen produces 484 kJ/mol.
The molar mass of hydrogen gas = 2g
The no. of moles in 1g of hydrogen = 1 / 2 = 0.5 mole
Therefore, the amount of energy released from burning 1g of hydrogen =
(0.5 mol / 2 mol) x 484 kJ / mol = 0.25 x 484 kJ/mol = 121 kJ/mol

Question (3)

Sum of heat of formation of products = H_2S + $4F_2$ = -21 + (4x0) = -21 kJ/mol

(N.B: Heat of formation of elements such as F = zero)

Sum of heat of formation of reactants = 2HF + SF_6 = (2x -273) + (-1220) = - 1776 kJ/mol

Change in heat content = heat of formation of products – heat of formation of reactants = -1776 – (-21) = -1776 + 21 = -1745 kJ/mol

Question (4)

If the density of solution = 1g/ml
Therefore, the mass (m) = 100g
Change in temperature (ΔT) = 6◦C
Specific heat © = 4.18 j/g◦C
The amount of absorbed heat = c. m. ΔT = 4.18 x 100 x 6 = 2508 J = 2.508 kJ

Question (5)

$$2C_8H_{18\,(l)} + 25\ O_{2\,(g)} \rightarrow 16\ CO_{2\,(g)} + 18\ H_2O_{(g)},\qquad \Delta H_c = -1367\ kJ/mol$$

Heat change of one mole of octane = - 1367 / 2 = - 683.5 kJ/mol

Question (6)

Eq. (1): $1/2\ N_{2\,(g)} + 1/2\ O_{2\,(g)} \rightarrow NO_{(g)}$ ΔH = +90.29 kJ/mol
Eq. (2): $1/2\ N_{2\,(g)} + O_{2\,(g)} \rightarrow NO_{2\,(g)}$ ΔH = +33.2 kJ/mol

We reverse equation no. (1) to get equation no. (3)
Eq. (3): $NO_{(g)} \rightarrow 1/2\ N_{2\,(g)} + 1/2\ O_2$ ΔH = - 90.29 kJ / mol.

By Adding equations (2) and (3) together and simplifying them, we get the real equation.

Therefore, the change in heat of the combustion of NO to NO_2 equals the sum of heat contents of equations (2) and (3) = 33.2 kJ/mol – 90.29 kJ/mol = -57.09 kJ/mol

Question (7)

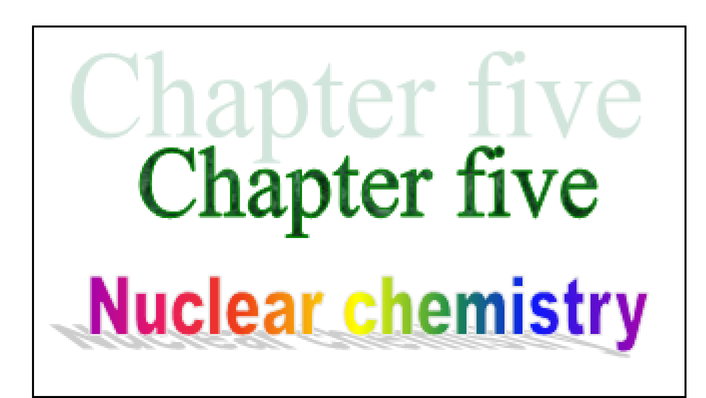
If the density of solution equals 1g/mol
Therefore, the mass of one liter of solution = 1000g
Specific heat of water (c) = 4.18 J/g◦C
Change in temperature ΔT = 20 – 14 = 6◦C

The amount of released energy = c. m. ΔT = 4.18 x 1000 x 6 = 25080 joules = 25.08 kJ

Question (8)

$$C_2H_5OH + 3O_2 \rightarrow 2\ CO_2 + 3H_2O, \quad \Delta H_c = -1367\ kJ/mol$$

Molar mass of ethanol = (12x2) + (6x1) + 16 = 46g
The no. of moles in 100g of ethanol = 100 / 46 = 2.17 moles
The amount of released heat = 2.17 x -1367 = 2966.39 kJ/mol



Lesson (1) Atomic nucleus and elementary particles
Lesson (2) Radioactivity and nuclear reactions

Lesson (1) Atomic nucleus and elementary particles



The Atom

→ *In late 19th century, scientists discovered that there are very tiny negative-charged particles in the atom called "electrons".*

Rutherford-Bohr atomic model

→ *After many experiments, scientist Rutherford (1871 – 1937) put a model to describe the atom with scientist Niels Bohr.*

<u>Description of Rutherford-Bohr atomic model</u>

1- Atom has a relatively heavy nucleus which carries positive charge.
2- The mass of atom is concentrated in its nucleus
3- Negatively-charged electrons rotate around the positively-charged nucleus in certain orbits called "electron levels"
4- Every energy level has a certain no. of electrons which cannot increase.

→ *Rutherford's calculations stated that:-*

- The radius of nucleus equals $4x\,10^{-15}\,m$
- The radium of atom equals $0.1x\,10^{-9}\,m$

→ *In 1932, Rutherford discovered that the nucleus contains positively-charged particles called "protons", the mass of proton is 1800 times greater than that of electron*

→ *In the same year (1932), James Chadwick discovered that nucleus contains also neutral particles with no charges called "Neutrons", the mass of neutron is nearly equal to that of proton*

Mass and atomic numbers

1- Atomic number (Z): The no. of positive protons in nucleus which equals the no. of negative electrons revolving around it.

2- Mass number (A): The no. of neutrons and protons in nucleus.

3- The number of neutrons (N) = Mass number (Z) – Atomic number (A)

→ *Protons and neutrons inside nucleus are called "Nucleons"*

→ *Atom is neutral because the no. of positive protons inside nucleus is equal to the no. of negative electrons revolving around it.*

Units used in nuclear physics

One femtometer (1 fm) = $10^{-15}\, m$

One nanometer (1 nm) = $10^{-9}\, m$

To change the measuring unit from meter to nanometer, we divide the number (in meters) by $10^{-9}\, m$ *and the same to femtometer*

Ex. The radius of atom in nanometers = $0.1x\,10^{-9}\, m \div 10^{-9}\, m$ *= 0.1 nm*

Nucleus symbol

The Nucleus

$^{A}_{Z}\mathbf{X}$

chemical symbol, *X*, for the element

atomic number, *Z*, equals the number of protons in the nucleus.

mass number, *A*, equals the number of nucleons (protons plus neutrons) in the nucleus.

neutron number, $N = A - Z$

Sometimes, we can describe the nucleus as the following: $^{A}_{Z}X_{N}$

Ex. Aluminium atom has 13 protons and 14 neutrons, its symbol is $^{27}_{13}Al$

Isotopes

Isotope: *Atoms of the same element which have the same number of protons but different number of neutrons.*

Isotopes atoms are similar in electronic configuration, the no. of electrons and chemical reactions.

Hydrogen isotopes:-

→ *Nucleus of hydrogen* $^{1}_{1}H$ *has one proton*

→ *The nucleus of hydrogen isotope which has a proton and a neutron* $^{2}_{1}H$ *is called "Deuterium"*

→ *The nucleus of hydrogen isotope which has a proton and two neutrons* $^{3}_{1}H$ *is called "Tritium"*

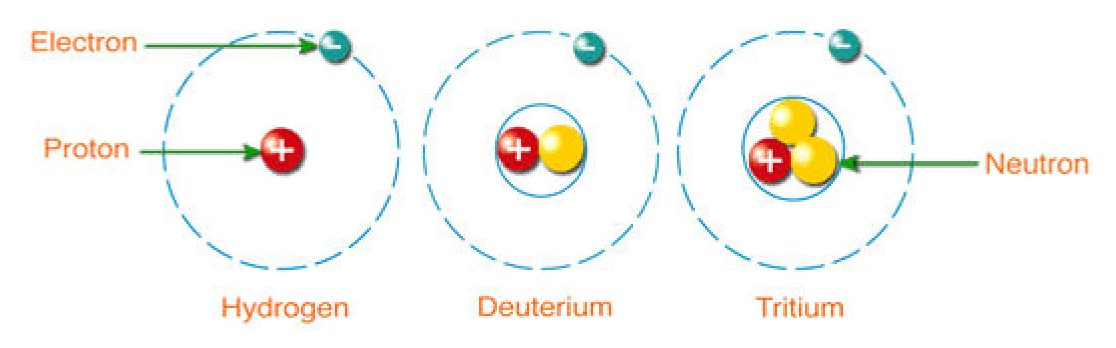


Fig. (1) Hydrogen isotopes

Oxygen isotopes

$^{16}_{8}O$ $^{17}_{8}O$ $^{18}_{8}O$

Carbon isotopes

$^{11}_{6}C$ $^{12}_{6}C$ $^{13}_{6}C$ $^{14}_{6}C$

→ *Most common carbon isotope in nature is* $^{12}_{6}C$ *, which exists in nature at ratio of 98.9%*

→ *Ratio of* $^{13}_{6}C$ *isotope in nature is 1.1%*

(N.B: There are stable and unstable isotopes in nature, and there are some isotopes which don't exist in nature, but prepared by nuclear reactions only)

Mass and energy units

→ *Scientists use a unit to measure the masses of atoms, this atom is called "atomic unit (a.m.u) of (u)"*

Atomic unit (a.m.u): *1/12 of the mass of carbon isotope* $^{12}_{6}C$

How to know the value of atomic unit

We know that the molar mass of cabon-12 atom equals 12g.

If One mole of carbon-12 has an Avogadro's number of atoms $6.02x\,10^{23}$ *atoms*

Therefore, the mass of $6.02x\,10^{23}$ *atoms of cabon-12 = 12g*

The mass of one carbon-12 atom = 12 $\div\ 6.02x\,10^{23}$

The mass of 1/12 of carbon atom = $(1 \div 6.02x\,10^{23})\ x\ (1 \div 12)$

$= 1.66x\,10^{-24}\,gm = 1.66x\,10^{-27}\,kg$

$1.66x\,10^{-24}\,gm$ $1.66x\,10^{-27}\,kg$

1 Atomic unit (u) =   =

Energy and mass equivalence

Scientist Albert Einstein discovered that energy can transform to energy and vice versa. When can calculate the amount of energy produced from the transformation of matter by using the following law

$$E = mc^2$$

E = The amount of energy (in joules)

M= Mass of matter being transformed to energy (in kilograms)

C = speed of light = $3x\,10^8\,m\,/\,s$

When matter of mass 1u transforms into energy (as what happens in nuclear reactions), we can calculate the amount of resulted energy by using Einstein's law as the following:-

Mass of atomic unit (in kilograms) = $1.66x\,10^{-27}\,kg$

Energy = mc2 = ($1.66x\,10^{-27}\,kg$ *) x* $(3x\,10^8)^2 = 14.94x\,10^{-11}\,Joule$

When can transform energy unit from joule to a smaller unit called mega electron volt (MeV) :-

$$Mev = 1.6x\,10^{-13}\,joules$$

Therefore, the amount of energy of 1u of matter in Mev =

$14.94x\,10^{-11}\,Joule \div 1.6x\,10^{-13}\,joules$ *= 931 MeV*

Therefore, there is equivalence between energy and mass

1 a.m.u ⇄ 931 Mev

Units of energy

MeV (million electron volt) = $1.6x\,10^{-13}\,joules$

***MeV =** 1,000,000 ev*

eV (electron volt)= $1.6x\,10^{-19}\,joules$

Nuclear forces

→ *There is a force binding nucleons (protons and neutrons) together inside nucleus, this force is known as "strong nuclear force"*

<u>Properties of strong nuclear force</u>

1- It is short-range force, as it doesn't bind two nucleons together unless the distance between them is less than (10^{-15} m)

2- It doesn't depend on the type of nucleons, and it is one of the following pairs (Neutron-Neutron), (Neutron-Proton), (Proton-Proton)

→ *When nucleons bind together forming nucleus, they lose their potential energy, which give them negative potential energy, the same happens when electrons enter their energy levels.*

→ *Nuclear forces bind positive protons together, making them overcome the repulsion forces (coulomb forces) between them*

Nuclear binding energy

<u>The importance of negative nuclear potential energy</u>

1- It is responsible for the stability of nucleus
2- It holds the components of nucleus together
3- It overcomes the repulsion forces between protons

*The difference between the potential energy of free nucleons and that of nucleons inside nucleus is called **"Nuclear binding energy"***

→ *Potential energy of free nucleons equals zero*
→ *Nuclear binding energy value is positive because the potential energy of nucleons is negative.*

<u>What is the source of nuclear binding energy</u>

→ *The mass of a cohesive nucleus is less than the sum of masses of its nucleons, because this difference is mass (Mass defect Δm) transforms into nuclear binding energy (which holds the components of nucleus together).*

$$\Delta m = (Zm_p + Nm_n) - M_x$$

ΔM = mass defect
Z= Number of protons
N= Number of neutrons
m_p = mass of proton = 1.007825 u
m_n = mass of neutron = 1.008665 u
M_x = Actual mass of nucleus

→ *A part of the mass of each nucleon inside nucleus transforms into energy, which is known as "Nuclear binding energy per nucleon"*

Nuclear binding energy per nucleon = BE ÷ A

BE = nuclear binding energy
A = Mass number (no. of neutrons and protons)

We can calculate the amount of nuclear binding energy by this law:-

$$BE = [\ (Zm_p + Nm_n) - M_x\ ] \times 931\ MeV = \Delta M \times 931\ MeV$$

Z= Number of protons
N= Number of neutrons
m_p = *mass of proton = 1.007825 u*
m_n = *mass of neutron = 1.008665 u*
M_x = *Actual mass of nucleus*

Example (1)

Calculate the nuclear binding energy per nucleon in $^{40}_{20}Ca$ *, if:-*
$^{40}_{20}Ca$ = 40.078 u, m_p = 1.007825 u, m_n = 1.008665 u

Solution:-

Number of protons (Z) = 20
Number of neutrons (N) = 20
Mass no. (A) = 40

$BE = [\ (Zm_p + Nm_n) - M_x\ ] \times 931\ MeV =$

$[\ (\ 20 \times 1.007825 + 20 \times 1.00865) - 40.78)] \times 931 =$

$[\ 40.3298 - 40.078] \times 931 = 234.4\ MeV$

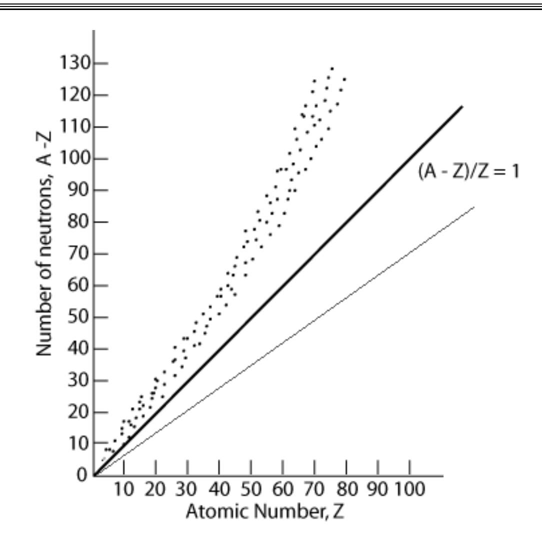
Nuclear binding energy per nucleon = BE / A = 234.4 /40 = 5.86 MeV.

Nucleus stability, (neutron / proton) ratio

Stable element: *Element whose nuclei remain stable over time*

Unstable element: *Element whose nuclei decay over time via radioactivity*

The following graph describe the relation between the no. of neutron and protons, and nucleus stability.



→ *The nuclei of stable light elements have equal no. of protons and neutrons (Z:N = 1 : 1). This ratio increases gradually in heavier elements of periodic table, till it reaches 1 : 1.6, as in lead* $^{208}_{82}Pb$

→ *If the ratio between protons and neutrons is more than 1.6, the nucleus becomes unstable because the no. of neutrons exceeded than the no. that required for stability. Such a nucleus achieves stability by changing one of excess neutrons into a proton, which radiate a negative electron called "Beta Particle* β *"*

→ *If the ratio between protons and neutrons is less than 1, the nucleus becomes unstable because the no. of protons is greater than that of neutrons . Such a nucleus achieves stability by changing one of the excess protons into a neutron which radiates a positive electron called "Positron"* β^{-}

→ *If a nucleus has great mass number, It becomes unstable. Therefore, the nucleus radiates (2 Protons + 2 Neutrons) in the form of a particle called Alpha particle α*

- Nuclei which have greater nuclear binding energy per nucleon are more stable

---

Elementary Particles

Scientists classify the elementary particles which form matter into:-

1- Leptons

2- Hadrons

Leptons

Leptons: *They are elementary particles which are not affected by strong nuclear energy, They don't have internal structure of definite mass*

Leptons are from the elementary particles which form matter <u>because they are not composed of smaller units and don't have internal structure</u>.

→ *Scientists discovered 6 types of leptons, one of them is electron.*

2- Hadrons

Hadrons: *A group of particles which form matter, they are affected by the fundamental forces of nature (Electromagnetic force, weak nuclear force, strong nuclear force, gravity)*

Hadrons are classified according to their masses into:-

1- Mesons: *They are unstable hadrons, they are heavier than baryons.*

2- Baryons: *Ex. Neutrons – Protons*

→ *Both mesons and baryons are heavier than leptons.*

Quark model

*Scientist Murray Gell-Mann discovered that hadrons are not elementary particles <u>because they are composed of smaller elementary particles called "**quarks**"</u>*

Quark: *An elementary particle forming hadrons which cannot exist freely.*

Murray Gell-Mann put quark model which states that:-
→ *All hadrons are composed of two or three types of quarks, these types are called:-*

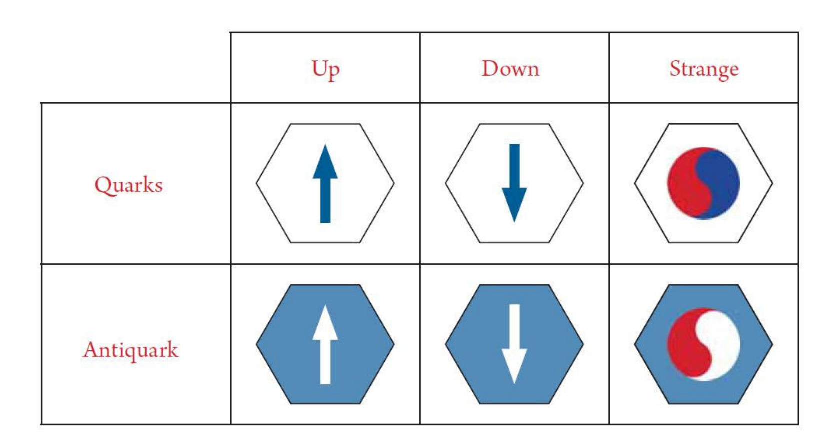
1- Up quark (u)

2- Down quark (d)

3- Strange quark (s)

→ *Each one of the previous quarks has an anti-body with opposite charge called "antiquark", their signs are* $\bar{s}$, $\bar{u}$, $\bar{d}$

Antiquark: *A quark which carries the opposite charge of the original quark*



Properties of quark

Each quark has three numbers, which are :-

1- Charge number (Q): *The number which describes the charge of quark (e) – The ratio between quark and electron charges.*

2- Baryon number (B): *it equals 1/3 in quarks, and – 1/3 in antiquarks*

3- Strangeness number (S): *It equals zero in up and down quarks, and equals -1 in strange quarks.*

Quark	Q	B	S
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	−1

Numbers of up, down and strange quarks

Anti-quark	Q	B	S
$\bar{u}$	$-\frac{2}{3}e$	$-\frac{1}{3}$	0
$\bar{d}$	$+\frac{1}{3}e$	$-\frac{1}{3}$	0
$\bar{s}$	$+\frac{1}{3}e$	$-\frac{1}{3}$	−1

Numbers of up, down and strange anti quarks

Example

A proton composed of quarks {u,u,d}, find the values of Q,B,S, and draw a diagram of it

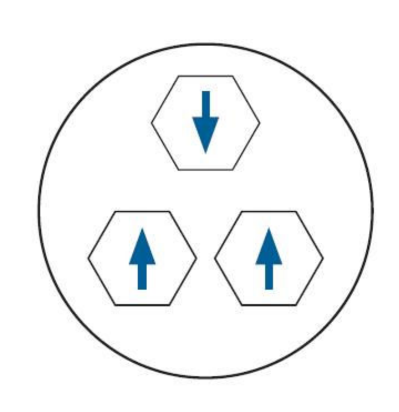
Solution

$$\text{Proton} = \{\ u \quad u \quad d\ \}$$

$$Q\ (+1e) = \left(+\frac{2}{3}\right) + \left(+\frac{2}{3}\right) + \left(-\frac{1}{3}\right)$$

$$B\ (+1) = \left(+\frac{1}{3}\right) + \left(+\frac{1}{3}\right) + \left(+\frac{1}{3}\right)$$

$$S\ (0) = 0 + 0 + 0$$



Definitions of lesson (1)

Isotopes: *Atoms of the same element which have the same atomic number (z), but different no. of neutrons (N)*

Nuclear forces: *They are forces which hold the nucleons of nucleus together.*

Elementary particles: *A group of particles which form matter, they are not affected by strong nuclear forces.*

Hadrons: *A group of particles which are composed of elementary particles called quarks, they are affected by the fundamental forces of nature (Electromagnetic force, weak nuclear force, strong nuclear force, gravity).*

Quark: *An elementary particle which cannot exist freely, it forms all types of hadrons.*

Antiquark: *A quark which carries the opposite charge of the original quark.*

Give reasons for

1- The actual mass of an atom is less that the sum of masses of its components.
Because that loss in mass (mass defect) is transformed into nuclear binding energy (which holds the nucleons of nucleus together) according to Einstein's law of the equivalence of mass and energy.

Famous scientists and their works

Ernest Rutherford:-
1- He put a model for the atomic structure with scientist Bohr.
2- He discovered protons in 1932

James Chadwick: *He discovered neutron in 1932*

Albert Einstein: *He put an equation which describes the equivalence of mass and energy.*

Murray Gell-Mann: *He discovered quarks in 1965.*

Questions

1- Choose the correct answer

1- Atomic unit (u) is ....

A- Mass of hydrogen atom B- Mass of proton C- Mass of neutron
D- Mass of 1/12 of carbon-12 atom.

2- If nuclear binding energy of $^{4}_{2}He$ equals 28 MeV, the nuclear binding force per nucleon equals.......

A- 7 B- 14 C- 56 D- 114

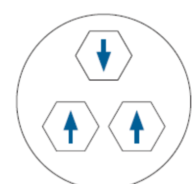
3- The difference between the sum of masses of nucleons forming iron nucleus and the actual mass of nucleus equals 0.5u, the nuclear binding energy equals

A- 0.5 MeV B- 0.5 Joule C- $0.8x10^{-19}$ MeV D- 465.5 MeV

4- When two nucleons approach to each other, their potential energy .....

A- Increases B- Decreases C- Doesn't change D- Becomes zero

5- The following diagram is a baryon, its type is ....



A- Meson B- Proton C- Neutron D- Electron

6- Nucleon is a name which describes ....

A- Neutrons and protons
B- Neutrons and electrons
C- Protons and electrons
D- Electrons and mesons

7- One of the following properties doesn't belong to isotopes.

A- They have similar chemical properties
B- They have similar atomic numbers
C- They have the same no. of neutrons
D- They have the same no. of protons

8- Strangeness number (S) of quark (u) equals

A- 0 B- + 1/3 C- + 2/3 D- 1

9- if the mass of neutron = m_1 , mass of proton = m_2, mass of helium nucleus = m_3, Therefore, the mass defect in MeV equals ....

A- $[(2m_1 + 2m_2) – m_3]C_2$
B- $[m_3 - (2m_1 + 2m_2)]C_2$
C- $[(2m_1 + 2m_2) – m_3]x 931$
B- $[m_3 - (2m_1 + 2m_2)]x 931$

Mass of proton = 1.007825 u
Mass of neutron = 1.008665 u
Speed of light = $3x10^8$ m/s
1 u = $1.66x10^{-27}$ kg

Question (2)

Use Einstein's equation to calculate the mass of matter which transforms into 190 MeV of energy.

Question (3)

Calculate the amount of energy in MeV resulted from the transformation of 5g of matter to energy

Question (4)

Calculate nuclear binding energy per nucleon (in MeV) of $^{16}_{8}O$ nucleus, if the mass of this nucleus = 15.994915 u

Question (5)

Which nucleus is more stable, $^{16}_{8}O$ or $^{17}_{8}O$, given that:-
Mass of nucleus of Oxygen-16 = 15.994915 u
Mass of nucleus of Oxygen-17 = 16.999132 u

Question (6)

Anti-proton is composed of quarks {u-, u-, d-}, calculate the values of S,B,Q

Question (7)

Calculate the nuclear binding energy of $^{12}_{6}C$ in:-
A- Joules
B- MeV

Question (8)

Calculate the binding energy of neutron in nucleus of $^{43}_{20}Ca$, given that:-
$^{43}_{20}Ca$ *= 42.958767 u*
$^{42}_{20}Ca$ *= 41.958618 u*
Mass of neutron = 1.008665

The answers

1- Choose the correct answer

1- Mass of 1/12 of carbon-12 atom
2- 7
3- 465.5 MeV
4- Decreases
5- Proton
6- Neutrons and protons
7- They have the same no. of neutron
8- 0
9- [(2m_1 + 2m_2) – m_3]x 931

Question (2)

If 931 MeV = 1 atomic unit (u)
Mass (in u) = 190 / 931 = 0.2 u = 3.32x10^{-28} Kg

Question (3)

5 g = 0.005 kg
Energy = mc^2 = 0.005 x (9x10^{16}) = 4.5x10^{14} joule

Question (4)

Actual mass of nucleus (M_x)= 15.994915 u
Mass no. (A) = 16
No. of protons (Z) = 8
No. of Neutrons (N) = A – Z = 8
Mass of proton (m_p) = 1.007825 u
Mass of neutron (m_n) = 1.008665 u

Mass defect(Δm) = (Zm_p + Nm_n) – M_x
(8 x 1.007825 + 8 x 1.008665) – 15.994915
= 16.13192 – 15.994915 = 0.137 u

Nuclear binding energy (BE) = Δm x 931 = 0.137 x 931 = 12.55 MeV

Binding energy per nucleon = BE / A = 127.547 / 16 = 7.97 MeV

Question (5)

Oxygen-16:-
Actual mass of nucleus (M_x)= 15.994915 u
Mass no. (A) = 16
No. of protons (Z) = 8

No. of Neutrons (N) = A – Z = 8
Mass of proton (m_p) = 1.007825 u
Mass of neutron (m_n) = 1.008665 u

BE = [($Zm_p + Nm_n$) – M_x] x 931 =
[(8x1.007825 + 8x1.008665) – 15.994915] x 931=
[16.1392 – 15.994915] x 931 = 127.55 MeV

BE per nucleon = 127.55 / 16 = 7.972 MeV

Oxygen-17
Actual mass of nucleus (M_x)= 16.999132 u
Mass no. (A) = 17
No. of protons (Z) = 8
No. of Neutrons (N) = A – Z = 9
Mass of proton (m_p) = 1.007825 u
Mass of neutron (m_n) = 1.008665 u

BE = [($Zm_p + Nm_n$) – M_x] x 931 =
[(8x1.007825 + 9x1.008665) – 16.999132] x 931=
[17.14 –16.999132] x 931 = 131.69 MeV

BE per nucleon = 131.69 / 17 = 7.746 MeV

→Oxygen-16 is more stable because it has higher nuclear binding energy per nucleon.

Question (6)

$$\text{Anti - Proton} = \{ \quad \bar{u} \quad \bar{u} \quad \bar{d} \quad \}$$

$$Q \ (-1e) = \left(-\frac{2}{3}\right) + \left(-\frac{2}{3}\right) + \left(+\frac{1}{3}\right)$$

$$B \ (-1) = \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right)$$

$$S \ (0) = 0 + 0 + 0$$

Question (7)

Actual mass of nucleus (M_x)= 12 u
Mass no. (A) = 12
No. of protons (Z) = 6
No. of Neutrons (N) = A – Z = 6
Mass of proton (m_p) = 1.007825 u

Mass of neutron (m_n) = 1.008665 u

A- BE = [($Zm_p + Nm_n$) – M_x] x 931 =
[(6x1.007825 + 6x1.008665) – 12] x 931=
[12.09894 – 12] x 931 = 92.1 MeV

B- BE (in joules) = 92.1 x 1.6x10^{-13} = 4.474x10^{-11} joules

<u>Question (8)</u>

Actual mass of neutron = 1.008665 u
Calculated mass of neutron = 42.958767 – 41.958618 = 1.000149 u
Mass defect (ΔM) = 1.008665 – 1.000149 = 0.008516 u
Binding energy of neutron (MeV) = 0.008516 x 931 = 7.93 MeV

Lesson (2) Radioactivity and nuclear reactions



History of radioactivity

→ *In 1896, Scientists Henri Becquerel discovered radioactivity phenomenon (Radioactivity is the activity associated with emitting radiation)*

→ *This phenomenon was given the name "Radioactivity" by Madame Curie.*

After radioactivity had been discovered, scientists sought to know the nature of radiations and their properties by two methods which are:-

1- The ability of radiation to penetrate substances
2- The effect of electric and magnetic fields on radiation.

There are three types of radiation, which are:-

1- Alpha particles: *Alpha particle is composed of two protons and two neutrons, we can say that every alpha particle is a helium nucleus* $^{4}_{2}He$ *, it is denoted by α*

2- Beta particles: *Beta particle is a negatively-charged particle which has the properties of electrons* $^{0}_{-1}e$ *. Its mass is negligible if compared to atomic unit (u). It carries negative charge (-1e) and denoted by β-.*

3- Gamma rays: *electromagnetic waves with short wavelengths whose speeds are equal to that of light. They are the shortest electromagnetic waves after cosmic waves. Therefore, their frequencies are high, and the energy of their photons are great. They are denoted by " γ"*

→ *Gamma rays don't carry any charges because they are electromagnetic waves.*

→ *Emission of gamma rays from nuclei don't decrease their mass or atomic numbers because they have no mass.*

→ *Unstable nuclei which have excess energy emit gamma rays to decrease their energy and achieve stability.*

The following table compares between the three kinds of radiation:-

Radiation	Symbol	Nature of radiation	Approximate mass	Ability to ionize atoms of medium it penetrates	Penetration ability	Deviation in electric and magnetic fields
Alpha	α $^{4}_{2}He$	*Helium nucleus*	*Mass of four protons*	*Strong*	*Weak – It cannot penetrate a paper*	*Small deviation*
Beta	β $^{0}_{-1}e$	*Electron*	*1/1800 of the mass of proton*	*Weaker than alpha*	*Aluminium sheet of thickness 5mm prevents its penetration*	*Great deviation*
Gamma	γ	*Electro-Magnetic wave*	*Massless*	*Has the Weakest ability*	*Has the greatest ability of penetration – It can penetrate lead sheet of some centimeters thickness, but it gets weaker*	*It doesn't Deviate in any of those two fields*



Half life: *The time in which half the number of nuclei in a radioactive element decay by means of radioactive decay.*

→ *When a nucleus undergoes radioactive decay, it emit alpha, beta or gamma radiations.*

→ *the ratio between the no. of element nuclei which decay per second and the no. of remained nuclei is constant.*

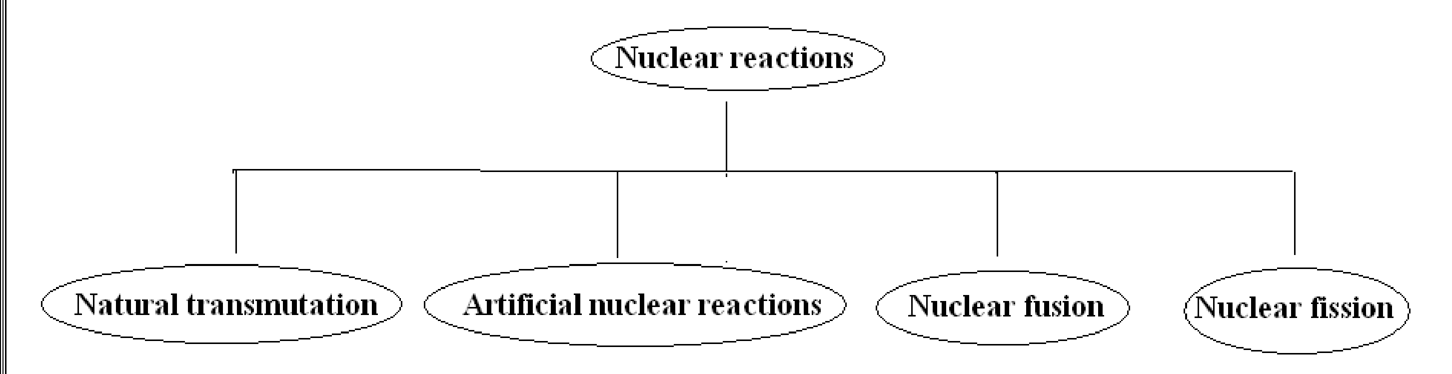
Ex. *When we say that half-life of radioactive iodine – 131 is 8 days, we mean that the no. of nuclei of this element decrease to half the real value by means of radioactive decay in 8 days.*

Importance of calculating half-life: *Determination of the age of mummies and stones*

Nuclear reactions

Nuclear reaction: *Changing the structure of reactant nuclei and forming new product nuclei when the nuclei of reactants collide with each other*

→ *Chemical reactions occur via the electrons of outermost energy levels of atoms, while the nuclear structure doesn't change.*



1- Natural transmutation

Natural transmutation occurs to nuclei whose ratio between protons (Z) and neutrons (N) is greater than the ratio required for stability.

Example (1) on natural transmutation

To achieve stability, Uranium-238 nucleus emits alpha particle, turning into thorium-234 nucleus.

$$^{238}_{92}U \rightarrow \, ^{234}_{90}Th + \, ^{4}_{2}He$$

Note: The mass no. (A) of uranium atom equals the sum of mass numbers of thorium and alpha particle on the right side of equation.

Example (2) on natural transmutation

To achieve stability, the unstable isotope of carbon-14 emits beta particle, turning into nitrogen atom.

$$^{14}_{6}C \rightarrow \, ^{14}_{7}N + \, ^{0}_{-1}e$$

→ *When a nucleus emits beta particle, a neutron turns into proton, which increases the atomic no. of nucleus (no. of protons)*

→ *Mass no. of beta particle (electron) is zero because its mass is negligible if compared to mass of proton or neutron.*

2- Artificial nuclear reactions

If we want two nuclei to react with each other, we accelerate one of them to get high energy, then we target it at the second nucleus.

The accelerated nucleus is called "Projectile", while the targeted nucleus is called "Target"

Examples of nuclear projectiles

1- Proton $_{1}^{1}H$

2- Deuteron $_{1}^{2}H$

3- Neutron $_{0}^{1}n$

4- Alpha particle $_{2}^{4}He$

Nuclei are accelerated by devices called "Nuclear accelerators"

Examples of Nuclear accelerators:-

1- Van de Graff accelerator
2- Cyclotron accelerator

Rutherford and the first artificial nuclear reaction

→ *In 1919, Rutherford carried out the first nuclear reaction in history.*

→ *When an alpha particle passed through nitrogen nucleus, it formed a nucleus of Fluorine* $_{9}^{18}F^{*}$

$$_{7}^{14}N + _{2}^{4}He \rightarrow [_{9}^{18}F^{*}]$$

→ *This fluorine nucleus is a compound nucleus, a compound nucleus is an unstable nucleus with massive energy.*

→ *Compound fluorine nucleus gets rid of excess energy by emitting a proton, which turns in into oxygen-17 nucleus*

$$[_{9}^{18}F^{*}] \rightarrow _{8}^{17}O + _{1}^{1}H$$

Examples on artificial nuclear reactions

1- $^{27}_{13}Al + ^{1}_{1}H \rightarrow [^{28}_{14}Si]^{*} \rightarrow ^{24}_{12}Mg + ^{4}_{2}He$

2- $^{26}_{12}Mg + ^{2}_{1}H \rightarrow [^{28}_{13}Al]^{*} \rightarrow ^{24}_{11}Na + ^{4}_{2}He$

3- $^{6}_{3}Li + ^{1}_{0}n \rightarrow ^{3}_{1}H + ^{4}_{2}He$

→ *When balancing nuclear equations, we should subject to the conservation laws of charge, energy and mass.*

Conservation law of charge: *The sum of atomic numbers on the right side of nuclear equation should equal the sum of atomic numbers on its left side*

Conservation law of energy and mass (in nuclear equations): *The sum of mass numbers on the right side of nuclear equation should equal the no. of mass numbers on its left side*

Balancing energy in artificial nuclear reactions

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

→ *When an alpha particle hits nitrogen nucleus, oxygen-17 nucleus and proton are produced with kinetic energy equals E_k.*
→ *Kinetic energy of alpha particle equals 7.7 MeV(equivalent to 0.0083u)*
→ *In nuclear reactions, the sum of energies and masses remain the same on both sides , we can balance them on the two sides of equation as the following:-*

Left hand side (L.H.S)
Energy of alpha particle = 0.0083u
Actual mass of alpha particle = 4.0039u
Actual mass of nitrogen nucleus = 17.0049u
Total = 18.0201 u

Right hand side (R.H.S)
Actual mass of oxygen-17 nucleus = 17.0045u
Actual mass of proton = 1.0081u
The sum of energy of both particles = E_k
Total = (18.0126 + Ek) u

If Left hand side = Right hand side

Therefore, 18.0201 = 18.0126 + Ek
Ek = 180.201 – 18.0126 = 0.0075 u
Ek (in MeV) = 0.0075 x 931 = 7 MeV (This energy is distributed between both oxygen- 17 nucleus and proton)

→ *This reaction is endothermic because the kinetic energy of reactant particles (7.7 MeV) is greater than that of product particles (7 MeV)*

3- Nuclear fission

Nuclear fission: *A nuclear reaction in which a nucleus splits into two smaller nuclei.*

Example:-

→*When a neutron bombards uranium-235 nucleus, it enters the nucleus, turning it into an unstable isotope called uranium-236*

*(**N.B**: Neutrons don't need to be accelerated because they are neutral projectiles – cannot be affected by charges in nucleus)*

→ *Uranium-236 splits within 10-12 seconds into 2 or 3 neutrons and two nuclei (X),(Y) – Those two nuclei are called nuclear fission fragments.*

→ *90 different fragments can be formed from such a reaction.*

$$ {}^{235}_{92}U + {}^{1}_{0}n \rightarrow [\,{}^{236}_{92}U\,] \rightarrow X + Y + 2 or 3 neutrons $$

→ *Barium and krypton are from the common fragments of nuclear fission of uranium.*

$$ {}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}U + {}^{92}_{36}Kr + 3n^{1}_{0} $$

4- Nuclear fusion

Nuclear fusion: *A nuclear reaction in which two light nuclei join to form a heavier nucleus*

Example:-
→ *When two deuteron nuclei fuse together, they form helium nucleus + neutron + energy*

$$ {}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n + 24MeV $$

→ *The difference between the mass of helium-3 and that of two deuteron nuclei transforms into energy of 24 mega electron volt.*

Requirements for nuclear fission

Very high temperature that may reach 10,000,000 (10^7) degree Celsius

→ It is hard to carry out nuclear fusion reactions in laboratories because they require very high temperature.

→ Nuclear fusion reactions occur in stars (such as sun) to produce energy because of their high temperatures.

→ Nuclear fusion is the source of the destructive power of hydrogen bomb

For reading only: *The first test of hydrogen bomb was carried out by the United States in November 1952 on a small island in the pacific ocean. This test was named "Ivy Mike"*

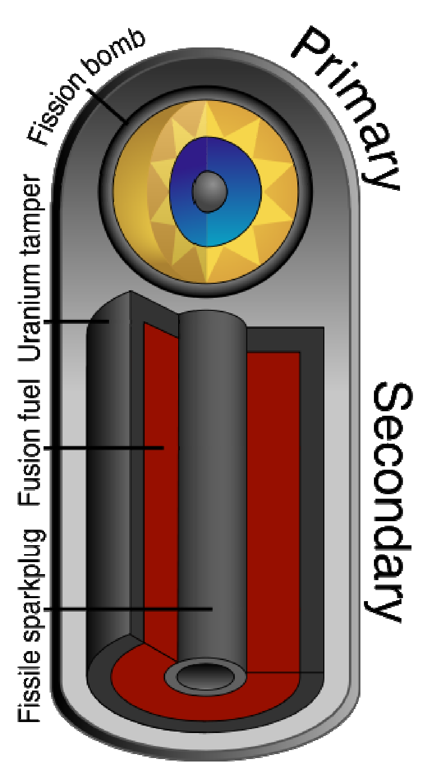


Fig. (2) Structure of hydrogen bomb

Nuclear reactor

→We said that nuclear fission reactions produce a group of neutrons and nuclear fragments.

*→ If the speed of produced neutrons is suitable, they will be able to split more uranium-235 nuclei, and so on. Such reactions are called "**chain reactions**"*

→ Chain reaction is the continuous split of uranium nuclei

→ Chain reactions produce huge heat energy which increases as the reaction goes on.

*→ Chain reactions are the basis of "**nuclear fission bombs**"*

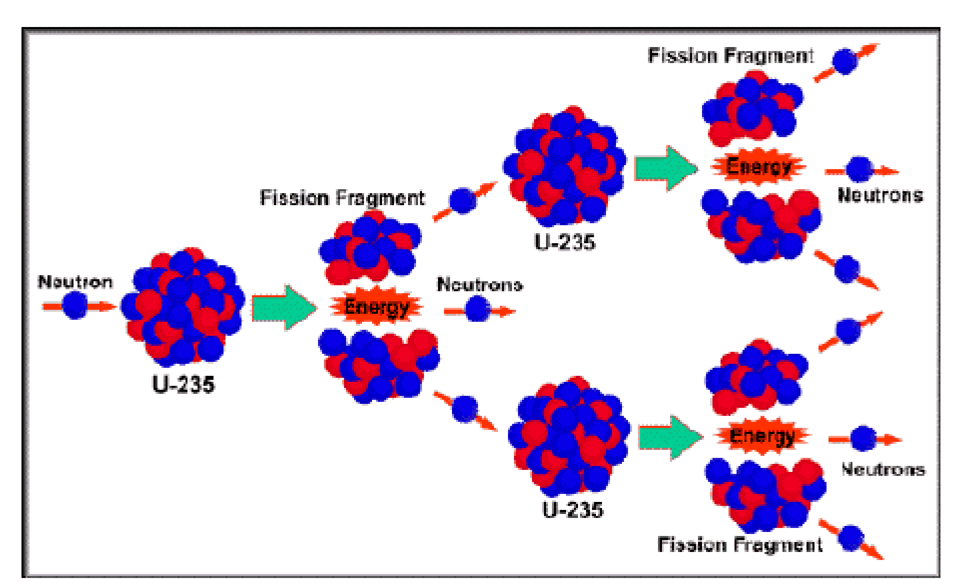


Fig. (3) Chain reaction of uranium

For reading only: *The first nuclear fission bomb in history was manufactured by the United States during world war II, its codename was "little boy". This bomb was dropped on Hiroshima, Japan on 6 August 1945, which cause the death 66,000 – 166,000 persons.*



Fig. (4) Little boy, the first nuclear fission bomb in history

→ *To sustain a nuclear chain reaction, we need a certain amount of uranium-235 called "critical mass"*

Critical mass: *The smallest amount of fissile material (uranium-235) needed for sustaining nuclear chain reaction*

→ *In critical mass of uranium, every nuclear fission reaction produces one neutron – in average – which begins another fission reaction. Therefore, chain reaction goes on with the same initial rate at the beginning of reaction.*

→ *If an amount of uranium of mass greater than critical mass is used, the reaction goes on with fast rate which causes the occurrence of explosion (This is required for the manufacture of nuclear fission bombs sometimes).*

<u>Cadmium rods and the control of chain reactions</u>

→ *Control rods (mainly made of cadmium) are used to control chain reactions in nuclear reactors , they control the number of neutrons by absorbing them, which prevents the occurrence of explosions and produces energy.*

→ *When putting cadmium rods inside the reactor, they slow down chain reactions. We can change the rate of chain reactions by controlling the position and number of cadmium rods.*

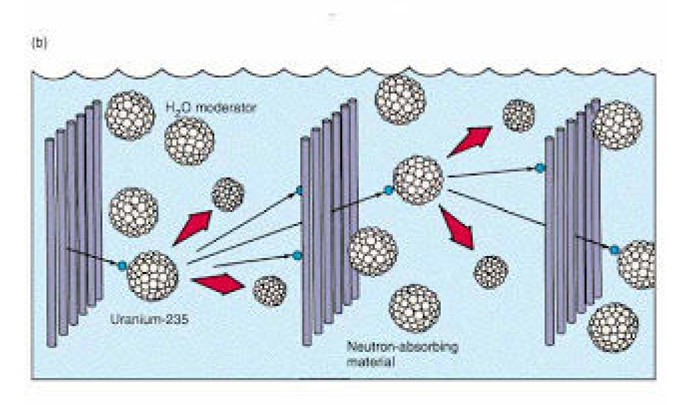


Fig. (5) How cadmium rods control the no. of neutrons

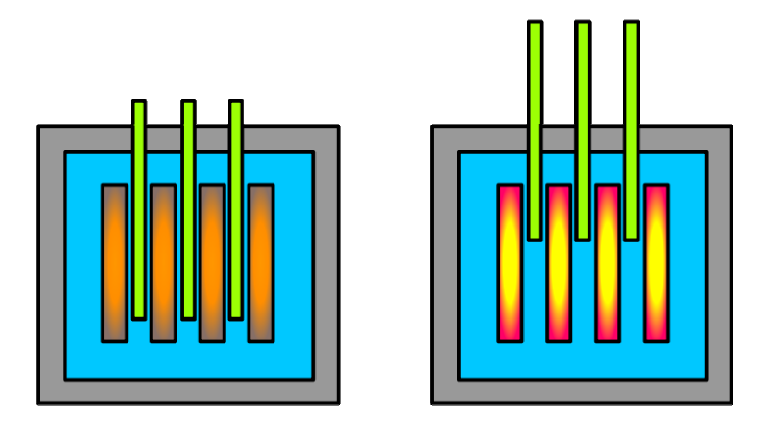


Fig. (6) Control rods inside reactor core

→ *Peaceful nuclear reactors are used in generating electricity.*

<u>For reading only:</u> *The first nuclear reactor in history was established at the university of Chicago in December 1942. It was a part of "Manhattan project" which aimed to manufacture the first atomic bomb during world war II. Whereas the first nuclear power plant used to generate heat was opened in July 1954 in Soviet union (Russia)*

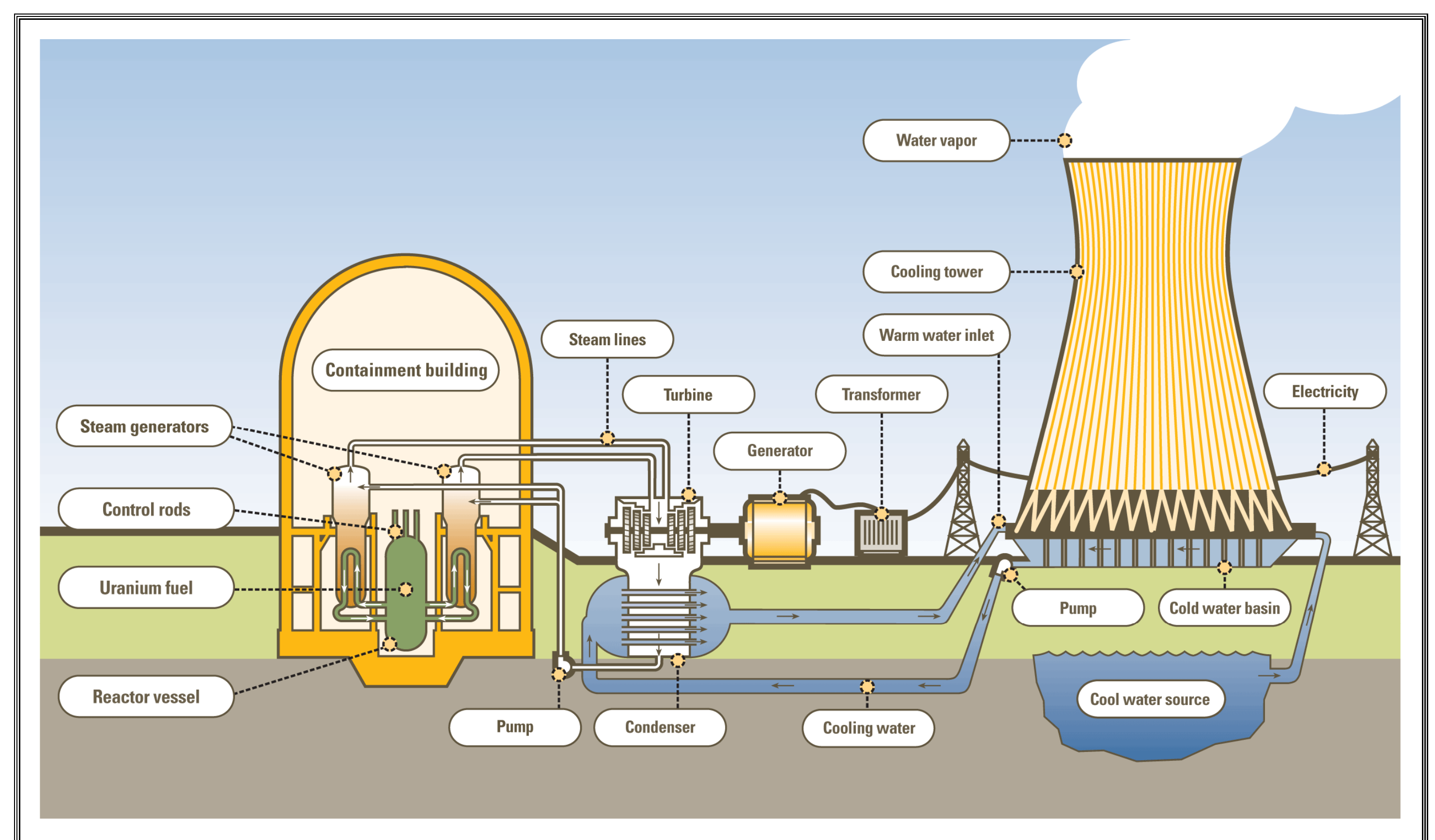


Fig. (6) Design of a nuclear reactor for generating electricity (For illustration only)

Comparison between chemical and nuclear reactions

Chemical reactions	***Nuclear reactions***
- They occur via the electrons in the outermost energy levels of atoms	*- They occur via the components of nucleus*
- They don't change an element to another one	*- Usually associated with change of element to another one or isotope.*
- Products of reaction don't change by the change of the isotopes of element	*- Every isotope of element gives different product*
- Gives out low energy	*- Gives out high energy*

Peaceful uses of radiation

Medicine

1- Gamma rays emitted from cobalt-60 and cesium-17 isotopes are targeted to the centre of cancerous tumor to kill cancerous cells.

2- Radioactive radium-226 needles are implanted into cancerous tumors to kill their cells

Industry

Gamma rays are used in the automatic control of some production lines.

Automatic control of pouring molten steel

→ Source of gamma rays (cobalt-60 or cesium-17) is put on one side of the pouring machine, and radiation detector (which receives gamma rays) is put on the other side.

→ When the mass of steel reaches certain dimensions, the detector becomes unable to receive gamma rays, which stops pouring molten steel.

Agriculture

1- Seeds are exposed to different dosages of gamma rays to help in:-

- *The occurrence of mutations in them*
- *choosing suitable seeds which give out more producing and more resistant plants*

2- Gamma rays are used to sterilize plant and animal products which:-

- *Protects them from damage*
- *Extends their storage periods*

3- Gamma rays are used to make male insects infertile to prevent the spread of pests.

Scientific researches

1- Research reactors are used to prepare radioactive isotopes which are being used in scientific researches.

2- We can know what happens inside plants by putting radioactive substances in substances used by plants, and tracking the radiations emitted from radioactive substances, which helps us know more about plant cycles
Ex. *Water with radioactive oxygen isotope is put in plant to know its path.*

Harmful effects of radiation

There are two kinds of radiation, which are

- Ionizing radiation: *Radiation which changes the structure of tissues it penetrates. It ionizes atoms when it hits them.*

Examples:-
1- Alpha particles
2- Beta particles
3- Gamma rays
4- X rays

*- **Non-ionizing radiation:** Radiation which doesn't change the structure of tissues it penetrates.*

Examples:-

1- Radio waves emitted from mobile phones
2- Microwaves
3- Light
4- Infrared waves
5- Ultraviolet waves
6- Laser waves

Harms of ionizing radiation

When ionizing radiation hits a cell, it ionizes water molecules in it which causes the damage of cell, occurrence of genetic changes and breaks up chromosomes.

→ water is the main component of cell, so when water molecules ionize, they damage cell badly.

In long-term, effects occur in cell which causes:-

- The death of cell

- Delay or prevention of cellular division or the increase of cell division rate which causes cancerous tumors.

- The occurrence of permanent changes in cell (mutations) which are inherited to the offspring; which causes the appearance of new babies different from their parents

Harms of non-ionizing radiation

1- Radiations emitted from mobile towers cause physiological changes to the nervous system. Thus, people who live near mobile towers suffer from headache, memory loss and sickness.

2- The electric and magnetic fields of radio waves which are emitted from mobile phones increase the temperature of cells because they absorb energy.

3- Putting laptop on knees affects the fertility of men.

Definitions of lesson (2)

Half life: *The time in which the no. of nuclei of a radioactive element decreases to half the real number by radioactive decay.*

Nuclear reaction: *Changing the structure of reactant nuclei and forming new nuclei when reactant nuclei collide with each other.*

Conservation law of charge: *The sum of atomic numbers on the right side of nuclear equation should equal the sum of atomic numbers on its left side.*

Nuclear fission: *A nuclear reaction in which a nucleus splits into two smaller nuclei.*

Nuclear fusion: *A nuclear reaction in which two light nuclei join to form a heavier nucleus.*

Critical mass: *The smallest amount of fissile material (uranium-235) needed for sustaining nuclear chain reaction.*

Give reasons for

1- Some radioactive nuclei emit alpha particles
To achieve stability, as their atomic numbers are very great.

2- Some radioactive nuclei emit beta particles
To achieve stability by turning a proton into neutron, as the ratio between the no. of protons (Z) and no. of neutrons (N) is less than the ratio required for stability.

3- Some particles emit gamma rays
In order to get rid of excess energy to achieve stability

4- Neither mass number nor atomic number changes when a nucleus emits gamma rays
Because gamma rays are electromagnetic waves that carry no charges, a nucleus emits them in order to get rid of excess energy to achieve stability

5- Nuclear fusion reactions cannot be conducted at laboratories
Because they require very high temperature that may reach 10 million degree Celsius

6- Nuclear chain reactions should be controlled
In order to produce energy and prevent the occurrence of explosions

7- Neutrons are used as nuclear projectiles in nuclear fission reactions
Because they are perfect projectiles, as they can enter nuclei without being repulsed because they are neutral

8- Control rods are used to control the rate of nuclear fission reactions
Because they control the no. of neutrons produced from nuclear fission by absorbing them.

9- Radiation plays an important role in the treatment of caner
Because:-
1- Gamma rays emitted from cobalt-60 and cesium-17 isotopes are used to kill cancerous cells by targeting them to the centre of tumor
2- Radioactive radium-226 needles are implanted into cancerous tumors to kill their cells

10- Radiation plays an important role in agriculture field
Because:-
1- Seeds are exposed to different dosages of gamma rays to help in:-
- *The occurrence of mutations in them*
- *choosing suitable seeds which give out more producing and more resistant plants*

2- Gamma rays are used to sterilize plant and animal products which:-
- *Protects them from damage*
- *Extends their storage periods*

3- Gamma rays are used to make male insects infertile to prevent the spread of pests.

11- Gamma rays are used in the sterilization of male insects
To prevent the spread of pests

12- Gamma rays are used to sterilize plants products
In order to extend their storage periods and protect them from damage

13- Seeds are exposed to dosages of gamma rays
to help in:-
- *The occurrence of mutations in them*
- *choosing suitable seeds which give out more producing and more resistant plant*

14- Radiation helps in scientific researches
Because:-
1- Research reactors are used to prepare radioactive isotopes which are being used in scientific researches.

2- We can know what happens inside plants by putting radioactive substances in substances used by plants, and tracking the radiations emitted from radioactive substances, which helps us know more about plant cycles

15- Ionizing radiation destroys living cells
Because it ionizes water molecules in cell which causes it damage, the occurrence of genetic changes and breaking up of chromosomes. Which causes in long-term

- The death of cell

- Delay or prevention of cell division or the increase of cell division rate which causes cancerous tumors.

- The occurrence of permanent changes in cell (mutations) which are inherited to the offspring

16- People who live near mobile towers suffer from loss in memory, headache and sickness
Because radiations emitted from mobile towers cause physiological changes to nervous system

17- Frequent use of mobile phones is bad for health
Because radio waves emitted from them increase the temperature of cells.

18- Men shouldn't put laptops on their knees
Because it affects their fertility

Questions

1- Choose the correct answer

1- Which one of the following properties belongs to gamma rays?
A- They have positive charge B- They have negative charge
C- They are composed of electrons D- They are electromagnetic waves

2- When ${}^{B}_{A}X$ nucleus emits an alpha particle, which equation describes the reaction
A- ${}^{B}_{A}X \rightarrow {}^{B-4}_{A-2}X + {}^{4}_{2}He$ B- ${}^{B}_{A}X \rightarrow {}^{B+4}_{A+2}X + {}^{4}_{2}He$
C- ${}^{B}_{A}X \rightarrow {}^{A-2}_{B-4}X + {}^{4}_{2}He$ D- ${}^{B}_{A}X \rightarrow {}^{A+2}_{B-4}X + {}^{4}_{2}He$

3- In the equation ${}^{4}_{2}He + {}^{9}_{4}Be \rightarrow {}^{12}_{6}C + X$, X stands for
A- Electron B- Proton C- Neutron D- Gamma ray

4- When thorium ${}^{228}_{90}Th$ decays to polonium ${}^{216}_{84}Po$ and ……. Alpha particles.
A- 2 B-3 C-4 D-5

5- When nucleus (X) emitted 5 alpha particles successively, it turned into nucleus of element ${}^{206}_{80}X$. The nucleus of (X) is …….
A- ${}^{216}_{82}X$ B- ${}^{216}_{90}X$ C- ${}^{226}_{94}X$ D- ${}^{226}_{90}X$

6- A sample of radioactive element has 4.8x10 12 atoms, if its half life equals two years, the no. of atoms after 8 years equals……….
A- 3x10 11 atoms B- 4.2x10 12 atoms C- 4.5x10 12 atoms D- 3.8x10 11 atoms

7- When nucleus ${}^{B}_{A}X$ emits an alpha particle then beta particle, it turns into nucleus ……
A- ${}^{B-4}_{Z-1}X$ B- ${}^{B-4}_{Z}X$ C- ${}^{B-1}_{A-4}X$ D- ${}^{B-1}_{A}X$

8- Which one of the following properties doesn't belong to alpha radiation?
A- Composed of helium nuclei
B- Most able to ionize air
C- Most able to penetrate air
D- Affected by electromagnetic field

9- After 12 minutes, 75% of nuclei of a radioactive element decayed, half-life of this element equals ….
A- 3 min. B- 4 min. C- 6 min. D- 9 min.

Question (2)

Compare between alpha and beta radiation in terms of:-

- Charge - Ability to penetrate air - Ability to ionize air.

Question (3)

Radium nucleus $^{220}_{88}Ra$ *decays giving an alpha particle. Write a balanced nuclear equation for this reaction*

Question (4)

Explain the stages of radiation damage to cells

Question (5)

Mention the harms of radiations emitted from mobile phones and laptops

Question (6)

Mention the difference between:-

- Chemical and nuclear reactions

- Nuclear fusion and nuclear fission

- Ionizing and non-ionizing radiation

Question (7)

Complete the following nuclear reactions:-

1- $^{226}_{88}Ra \rightarrow {}^{4}_{2}He + ...$

2- $^{9}_{4}Be \rightarrow {}^{4}_{2}He + ...$

3- $^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{1}_{1}H + ...$

Question (8)

Balance energy of the following reaction:-

$$^{1}_{1}H + {}^{3}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n$$

- E_k *of proton = 2 MeV*
- *Mass of tritium (H-3) = 3.0170 u*
- *Mass of helium-3 = 3.0170 u*
- *Mass of proton (H-1) = 1.0081u*
- *Mass of emitted neutron = 1.0089 u*

The Answers

1- Choose the correct answer

1- They are electromagnetic waves

2- equation (A)

3- Neutron $^{1}_{0}n$

According to the conservation law of charge:-
The sum of mass no. of left side = The sum of mass no. of left side
4+9 = 12 + x
Therefore, Mass no. of X = 4+9 – 12 = 1
The sum of atomic no. of left side = The sum of atomic no. of right side
2+4 = 6 + x
Therefore, Atomic no. of X = 2+4 – 6 = 0
The nuclear symbol of X is $^{1}_{0}X = ^{1}_{0}n$

4- 3

Difference in mass no. between thorium and polonium = 228 – 216 = 12
The mass no. of alpha particle = 4
No. of alpha particles = 12 / 4 = 3 Particles

5- $^{226}_{90}X$

Mass no. of alpha particle = 4
Sum of mass no. of 5 alpha particles = 5 x 4 = 20
Atomic no. of alpha particle = 2
Sum of atomic no. of 5 alpha particles = 5 x 2 = 10
Mass no. of nucleus (After decay) = 206
Atomic no. of nucleus (After decay) = 80
Mass no. of nucleus (before decay) = 206 + 20 = 226
Atomic no. of nucleus (before decay) = 80 + 10 = 90

6- $3x10^{11}$ *atoms*

$$4.8x\,10^{12} \xrightarrow{2\,years} 2.4x\,10^{12} \xrightarrow{2\,years} 1.2x\,10^{12}$$

$$1.2x\,10^{12} \xrightarrow{2\,years} 0.6x\,10^{12} = 6x\,10^{11} \xrightarrow{2\,years} 0.3x\,10^{12} = 3x\,10^{11}$$

7- $^{B-4}_{X-1}X$

8- Most able to penetrate air

9- 6 min.

After 12 min, 75% of nuclei decayed. Therefore, 25% of nuclei remained.

$$100\% \xrightarrow{period\ (1)} 50\% \xrightarrow{Period\ (2)} 25\%$$

Time = 12 min.
No. of periods = 2
Half-life = Time / no. of periods = 12 / 2 = 6 min.

Question (2)

	Alpha radiation	Beta radiation
Charge	Positive (+2e)	Negative (-1e)
Ability to ionize air	Strong	Weaker than alpha
Ability to penetrate air	Relatively weak	Stronger than alpha

Question (3)

Radium-220 decays into an alpha particle and Radon-16 nucleus

$$^{220}_{88}Ra \rightarrow {}^{4}_{2}He + {}^{216}_{86}Rn$$

Question (4)

See (harms of ionizing radiation)

Question (5)

Radiation emitted from mobile: Increase the temp. of cells
Radiation emitted from laptop: Affects fertility of men

Question (6)

Chemical reactions	Nuclear reactions
- They occur via the electrons in the outermost energy levels of atoms	- They occur via the components of nucleus
- They don't change an element to another one	- Usually associated with change of element to another one or isotope.
- Products of reaction don't change by the change of the isotopes of element	- Every isotope of element gives different product
- Low product energy	- High product energy

Nuclear fusion	*Nuclear fission*
- Nuclear reaction in which two light nuclei fuse into one heavier nucleus	*- Nuclear reaction in which a nucleus splits into two lighter nuclei*

Ionizing radiation	*Non ionizing radiation*
- Radiation which changes the structure of tissues it penetrates, and ionizes the atoms it hits.	*- Radiation which doesn't change the structure of tissues it penetrate, and doesn't ionize the atoms it hits*

Question (7)

$$1-\ {}^{226}_{88}Ra \rightarrow {}^{4}_{2}He + {}^{222}_{86}Rn$$

$$2-\ {}^{9}_{4}Be \rightarrow {}^{4}_{2}He + {}^{5}_{2}He$$

$$3-\ {}^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{1}_{1}H + {}^{17}_{8}O$$

Question (8)

Right hand side:-

Mass of helium-3 = 3.0170 u

Mass of neutron = 1.0089u

Kinetic energy of particles = E_k

Sum of masses of right hand side = $(4.0259 + E_k)$ u

Left hand side:-

*E_k of proton = **2 MeV** = 0.002 u*

Mass of proton = 1.0081 u

Mass of tritium = 3.0170 u

Sum of masses of left hand side = 4.0272 u

Right hand side = Left hand side

$4.0259 + E_k = 4.0272$

*E_k of products = 4.0272 – 4.0259 = 0.0013 u = 0.0013 x 931 = **1.2 MeV***

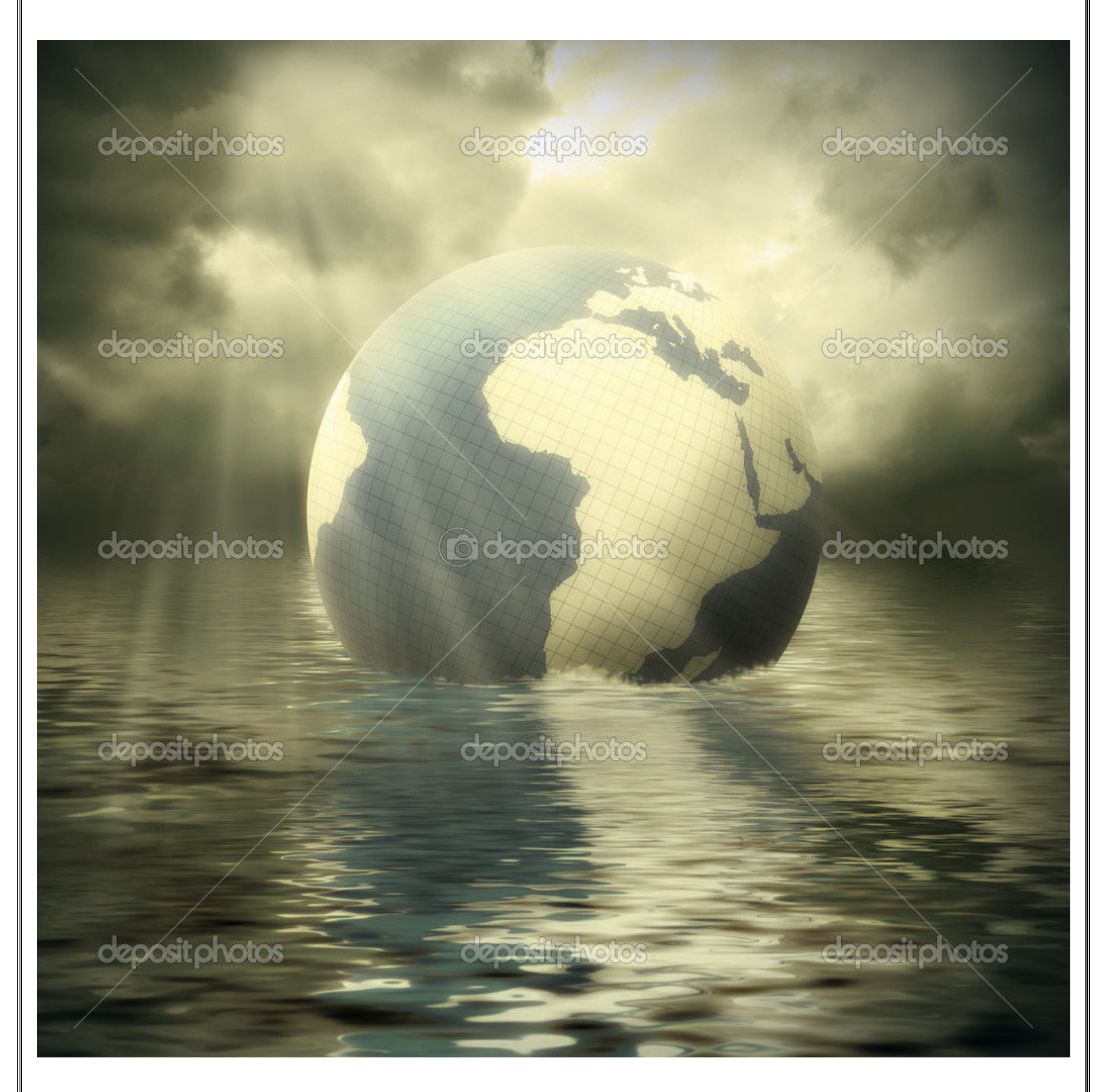
→ This nuclear reaction is endothermic because the energy of products is less than that of reactants.



Lesson (1) Environmental pollution

Lesson (2) Reducing pollution

Lesson (1) Environmental pollution



Environment: *Everything around human including physical, chemical and social effects which influence human's health and social activity*

Pollution

Pollution: *Quantitative and qualitative changes in the living and non living components of environment due to human's different activities which disorder the ecosystem.*

Air pollutants

Atmosphere of earth consists of 21% of oxygen, 78% of nitrogen and other gases (carbon dioxide, water vapour, inert gases).

This structure of air is very important for living organisms because:-
- Plants use carbon dioxide and nitrogen gases in growth and making their food.
- All kinds of living organisms need oxygen gas for respiration and performance of vital processes

→ When the structure of air changes (if harmful gases mixed with it), it becomes polluted.

Air pollutants are classified to :-

First: Primary pollutants

They are pollutants which pollute air directly, such as:-

Carbon oxides (CO_x):-

Carbon dioxide (CO_2)

This gas is produced by different living organisms from respiration process. It becomes harmful if its ratio increased in air.

How does CO_2 ratio increases in air:-
CO_2 is one of the products of hydrocarbons combustion, the following equation describes the combustion of butane producing CO_2

$$2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(g)}$$

Harms of CO_2 :-
- Increases the temperature of earth
- Causes global warming phenomenon

Carbon monoxide (CO)

Carbon monoxide is a colourless and odorless gas

How does CO form?

It is formed as a result of the incomplete oxidation of fuel. For this, it is from the main components of car exhausts (especially in crowded cities), as in the following equation

$$C_4H_{10(g)} + 5O_{2(g)} \rightarrow 5H_2O_{(g)} + 2CO_{2(g)} + CO_{(g)} + C_{(s)}$$

Harms of carbon monoxide

It is more capable than oxygen of linking with hemoglobin of red blood cells, which decreases the ability of these cells to transport oxygen. When CO ratio increases in body it causes:-

- Headache
- Nausea
- Fainting
- Death

Sulphur oxides (So_x)

→ *They are produced naturally from volcanoes.*

→ *They are produced industrially as secondary products in industries which are to do with the extraction of metals from petrol derivatives (containing Sulphur – which oxidizes into Sulphur dioxide):-*

$$2Cu_2S_{(s)} + 3O_{2(g)} \rightarrow 2Cu_2O_{(s)} + 2SO_{2(g)}$$

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$$

→ *Sulphur dioxide gas is from main causes of acid rains because it reacts with water forming Sulphur trioxide gas, which forms sulphuric acids when dissolving in water:-*

$$2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$$

$$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$$

Harms of acid rains:-

- They cause the corrosion of buildings interfaces, as sulphuric acids changes calcium carbonates ($CaCO_3$) into calcium sulphate (which dissolves in water at bigger degree)

$$H_2SO_{4(aq)} + CaCO_{3(s)} \rightarrow CaSO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$$

- They harm eye cornea and respiratory system

Nitrogen oxides (NO_x)

How do nitrogen oxides form?

- Formed when burning fuel in cars, lorries, power plants…etc

→ Nitrogen reacts with oxygen inside the places of fuel combustions forming nitric oxide (NO), which reacts with atmospheric oxygen forming nitric dioxide (NO_2)

$$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$$

$$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$$

Harms of nitrogen oxides

- Nitrogen oxides participate with Sulphur dioxide gas in the formation of acid rains, as nitrogen oxides react with water vapour forming nitric acid (strong acid)

$$4NO_{2(g)} + 2H_2O_{(g)} + O_{2(g)} \rightarrow 4HNO_{3(aq)}$$

- Mixture of nitric acid and nitrous acid (HNO_2) resulted from thunderstorm acid rains affects nervous system.

Second: Secondary pollutants

They are pollutants which are resulted from the reaction of primary pollutants with each other, for examples:-

Smog (smoky fog)

Smog appears in cities due to:-

- The combustion of fuel in engines of cars and means of transport

- Burning of grass and agricultural wastes in developing countries

How does smog form?

→ The incomplete combustion of fuel in internal combustion devices produces carbon dioxide gas, carbon monoxide gas, nitrogen oxides and organic compounds (which weren't completely oxidized).

→ This gaseous mixture is exposed to the ultraviolet rays of sun causing light chemical reaction which forms smog (smoky fog)

→ These smoky fogs stay suspended in the air and envelope the atmosphere of city.

Harms of smoky fogs (smogs)

They cause:-

- Mucus membranes sore

- Coughing

- Suffocation

- Eyes irritation

Ozone gas (O_3)

How does ozone gas form on earth?

It is formed when atmospheric oxygen gets exposed to high electric charges by electric power stations and electric transformers.

Harms of ozone gas.

- Ozone gas is very poisonous when it becomes near to the earth surface which causes the irritation of respiratory system

- It damages plants and many substances (Ex. Rubber and industrial threads)

How does ozone gas form in atmosphere

It is formed in the upper layer of atmosphere due to the electric discharge in clouds during the occurrence of lightning.

Importance of ozone layer

Ozone gas accumulates forming ozone layer, which works as protective shield which allows the penetration of small ratio of ultraviolet rays produced from sun, which protects living organisms from UVR bad effects such as skin cancer and cataract.

→ Ozone layers decay due to :-

- Leakage of chlorofluorocarbon gas (Freon) which is used in air conditioners and as a propelling substances in aerosols; which allows the leakage of UVR in great ratios which harm living organisms.

Water pollutants

→ Freshwater forms 3% of the total volume of water on the surface of the earth, water pollution is very dangerous to living organisms, and these are examples of water pollutants:-

Petrol:-

→ The amounts of petrol which are being leaked in seas and oceans are from the most common water pollutants in the world.

→ The most common causes are oil spills caused by oil tankers.

Harms of petrol

- It forms a thin layer on water surface, which prevents water and light from reaching sea creatures which leads to their death.

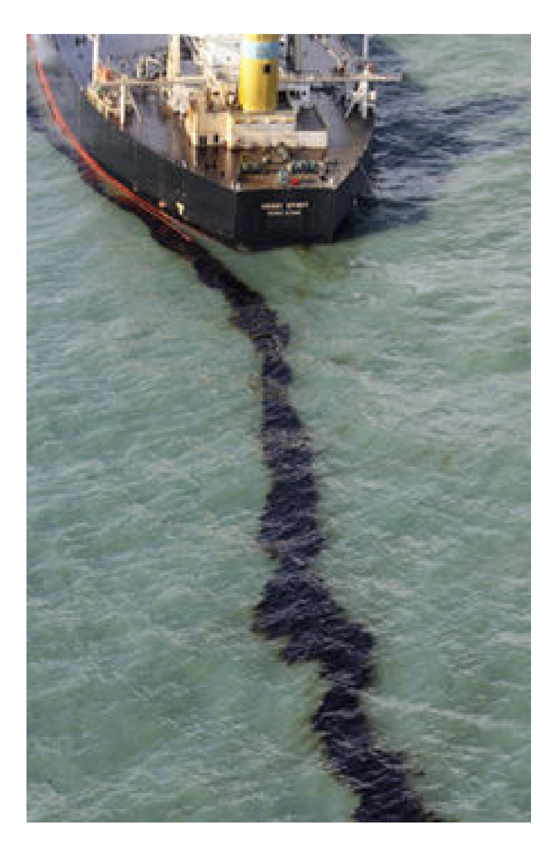


Fig. (1) Oil tanker spills some oil

Sewage water:-

Sewage water of cities, countries and residential communities are drained to agricultural drains and inland lakes without treatment.

Harms of sewage water:-

They contain many organic, inorganic and microbiological pollutants which:-

- Spoils water

- Makes water a suitable climate for bacteria reproduction causing microbial pollution (which affects human's health and crops being watered by it)

Insecticides and chemical fertilizers

→ The excessive use of insecticides led to the pollution of water surfaces with organic pollutants, either directly by throwing it in water or indirectly by agricultural drainage water which pours in them.

→ A part of these insecticides leaks to underground water, which is dangerous for human.

Soul pollutants

1- Poisonous heavy elements (Ex. Lead – Cadmium – Arsenic – Mercury)
2- Poisonous gases (Ex. Methane – Carbon dioxide – Hydrogen sulphate)
3- Organic pollutants (Ex. Oils – solvents – Phenolic compounds)
4- Chemical fertilizers
5- Insecticides
6- Acid rains

Global warming

→ Earth is a cold planet and doesn't have self-energy to warm it, but the light energy of sun warms it.

→ Earth climate is formed due to the balance of sun energy with chemical processes and physical phenomena.

→When sun sets, Earth releases a part of the energy it absorbed from the sun in the form of infrared rays. Then, global warming gases form a 'greenhouse' around the earth which absorbs these infrared rays and gives them back to earth. This natural phenomenon increases Earth's temperature.

→ Without this phenomenon, the temperature of earth will fall to the extent which is not suitable for life on it.

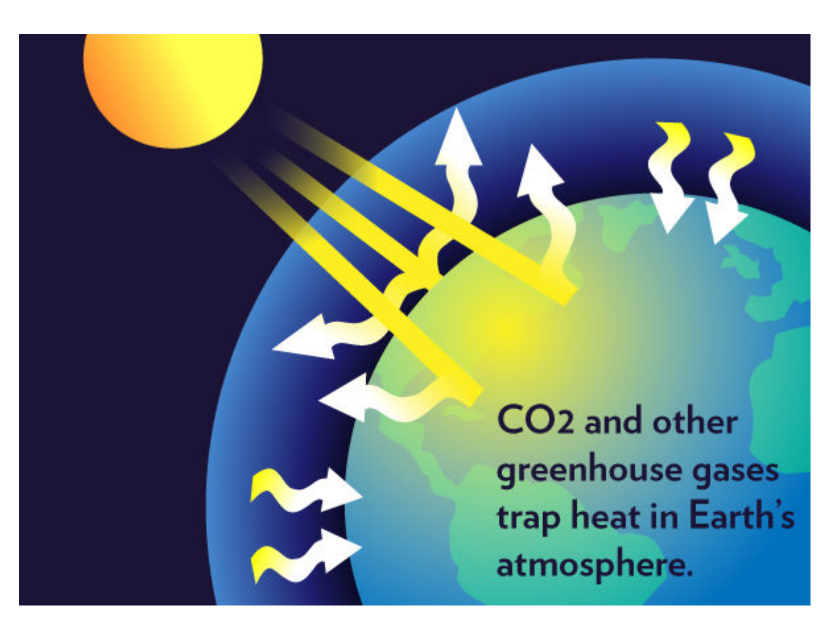


Fig. (2) Greenhouse effect

→ Some human activities increase the percentage of global warming gases in atmosphere, which changes the climate of earth and increases its temperature.

→ Global warming gases are also called greenhouse gases.

Examples of greenhouse (global warming) gases:-

- Carbon dioxide

- Methane

- Chlorofluorocarbon (Freon)

- Water vapour

- Nitrogen oxides

Global warming: *The gradual increase of lower atmosphere layer temperature due to the emission of greenhouse gases.*

For reading only: ***Scientists Arrhenius was the first to coin the term "Global warming" in 1896. He stated that combustion of petroleum increases carbon dioxide gas amount, which increases the temperature of earth.***

Emission of greenhouse gases causes

1- Combustion of fuel, which causes the emission of billion tons of carbon annually, and great amounts of methane and nitrogen oxides

2- Overcutting of trees without planting new ones, which increases the ratio of carbon dioxide gas

3- Rice farms, rubbish dumps and huge livestock sectors which cause the emission of methane gas.

4- Using fertilizers which produce nitrogen oxides.

Harmful effects of global warming phenomenon on environment

1- Melting of ice which causes the increase of sea level, drowning of islands and coastal cities, and the increase of floods.

2- The occurrence of drought and desertification of huge areas of earth

3- The extinction of many living organisms

4- The occurrence of natural disasters

5- Loss of number of crops

6- Increase of forest fires

Green chemistry

Green chemistry: *A modern branch of chemistry which aims to protect the environment by decreasing the emissions resulted from chemical industries as possible.*

Green chemistry aims:-

1- Creating new chemical substances which benefit the environment

2- Creating chemical substances which work as alternatives for:-

** Chemicals which harms the environment*

** Chemical substances extracted from endangered living organisms (Ex. Liver oils which are extracted from whales and sharks)*

→ Green chemistry aims to solve environmental pollution problem radically by stopping the formation of pollutants. , instead of the treatment, shrinking and control of pollution after its occurrence

Basic principles of green chemistry

1- The manufacture of biodegradable products.

2- Reduction of wastes

3- Achievement of atomic economy principle

4- Chemical preparations shouldn't be harmful to environment

5- Reduce creating harmful chemicals

6- Using eco-friendly catalysts.

7- Reduce the amount of consumed energy

8- Reduce the use of solvents and catalysts

Applications of green chemistry

Using glucose in the manufacture of plastic

→ Plastic industry was developed by using genetically-modified bacteria called "biological catalysts".

→ Glucose (simple sugar) replaces benzene in plastic (as benzene is bad for human's health)

Green plastics

→ Some kinds of green natural plastics are made of a mixture of natural fibres and proteins of soya beans.

→ Experiments are conducted to manufacture green plastics from wheat plant.

→ Green plastics are being treated physically and chemically to give them solidity and permanence (which suits the nature and period of using it). Then they decay by weather conditions leaving the ecosystem.

Depending on renewable energy resources

→ We depend on renewable energy resources to get the primary raw materials used in chemical industries.

→ This supports biological techniques by using plants to get energy, such as:-
- The manufacture of biological diesel.
- The manufacture of biological textiles.
- Using corn alcohol as fuel for cars
- Production of human proteins from genetically-modified rubber trees.
- Using wet windows instead of air conditioners.

Recycling biological wastes.

Biological wastes are being recycled by:-
- Treatment via anaerobic and aerobic fermentation
- Fermentation process
- Fermentation process via worms

Definitions of lesson (1)

Environment: *Everything around human including physical, chemical and social effects which influence human's health and social activity.*

Pollution: *Quantitative and qualitative changes in the living and non living components of environment as a result of human's different activities which disorder ecosystems.*

Primary pollutants: *They are pollutants which pollute air directly.*

Secondary pollutants: *They are pollutants resulted from the reaction of primary pollutants or other substances together.*

Global warming phenomenon: *The gradual increase of temperature of the lower layer of atmosphere which is near to earth surface.*

Green house effect: *Effect which happens due to the emission of different gases fro pollution sources, which makes the atmosphere acts like a greenhouse.*

Green chemistry: *A modern branch of chemistry which aims to protect the environment by decreasing the emissions resulted from chemical industry as possible.*

Give reasons for

1- The increase of CO_2 ratio in air is harms the environment
Because it increases the temperature of earth and causes global warming phenomenon.

2- Ratios of carbon oxides resulted from fuel combustion depends on the ratio of oxygen gas.
Because carbon oxides are from the products of fuel (hydrocarbon) combustion in oxygen. So, the ratio of carbon oxides depends on oxygen ratio.

3- Carbon monoxide is more dangerous that carbon dioxide.
Because carbon monoxide is more capable than oxygen of linking to hemoglobin in red blood cells, which affects their ability to transport oxygen in the body. The increase of CO ratio also causes headache, nausea, fainting, and even death!!

4- Sulphur oxides are produced naturally and industrially
Because Sulphur oxides are produced naturally from volcanoes, and industrially as a result of the process of extracting metal from petrol derivatives.

5- There is a relation between the increase of Sulphur dioxide in atmospheric air and the corrosion of building interfaces.
Because Sulphur dioxide reacts with water vapour forming Sulphur trioxide, which dissolves in water forming sulphuric acid. Then, sulphuric acid reacts with calcium carbonate (limestone) of buildings forming Sulphur carbonate (which dissolves in water causing the corrosion of buildings).

$$2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$$
$$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$$
$$H_2SO_{4(aq)} + CaCO_{3(s)} \rightarrow CaSO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$$

6- Acid rains affect human's health
Because they harm both eye cornea and respiratory system.

7- Nitrogen oxides are formed as a result of fuel combustion.
Because nitrogen gas reacts with oxygen inside the places of fuel combustion forming nitric oxide, which reacts with water vapour forming nitric dioxide.

8- There is a relation between the occurrence of thunders and increase of nitrogen oxides ratio.
Because thunders increase the ratio of nitrogen oxides - nitric acid (HNO_3) and nitrous acid (HNO_2)- in air, which affects the nervous system.

9- Sulphur oxides are primary pollutants, whereas acid rains are secondary pollutants.
Sulphur oxides are primary pollutants because they pollute air directly from pollution source. On the other hand, acid rains are secondary pollutants because they are formed from the reaction of primary pollutants or other substances together.

10- Nitrogen oxides contribute in acid rains formation
Because Nitric oxides react with oxygen and water vapour forming nitric acid, which is a strong one.

$$4NO_{2(g)} + 2H_2O_{(g)} + O_{2(g)} \rightarrow 4HNO_{3(aq)}$$

11- The formation of smoky fogs (smog)
Due to the incomplete combustion of fuel which produces carbon dioxide gas, carbon monoxide gas, nitrogen oxides and organic compounds. That mixture of gases reacts with ultraviolet rays of sun forming smoky fogs which stay suspended in the air.

12- Smoky fogs (smogs) are bad for human's health
Because they cause mucus membrane sore, coughing, eyes irritation and even suffocation sometimes!!

13- When ozone gas becomes near to the earth surface, it harms the environment.
Because ozone gas is very poisonous to living organisms, and damages plants, rubber and industrial threads.

14- The importance of ozone layer
Because it protects us from harmful ultraviolet radiations emitted from the sun.

15- The formation of ozone gas in atmosphere
Due to the electric discharge in clouds during the occurrence of lightning.

16- The decay of ozone layer
Due to the excessive use of chlorofluorocarbon gas (Freon) which is used in air conditioner and aerosols.

17- Oil (petrol) spill in water is very dangerous to sea creatures.
Because oil forms a thin layer on water, which prevents air and water reach sea creatures causing their death.

18- Sewage water is very harmful to environment
Because it contains many organic, inorganic and biological wastes which cause microbial pollution and spoil water.

19- The emission of greenhouse gases.
1- Combustion of fuel, which causes the emission of billion tons of carbon annually, and great amounts of methane and nitrogen oxides

2- Overcutting of trees without planting new ones, which increases the ratio of carbon dioxide gas

3- Rice farms, rubbish dumps and huge livestock sectors which cause the emission of methane gas.

4- Using fertilizers which produce nitrogen oxides.

20- Global warming phenomenon has bad effects on the environment

Because it causes:-

1- Melting of ice which causes the increase of sea level, drowning of islands and coastal cities, and the increase of floods.

2- The occurrence of drought and desertification of huge areas of earth

3- The extinction of many living organisms

4- The occurrence of natural disasters

5- Loss of number of crops

6- Increase of forest fires

Important chemical reactions

$$1-2C_4H_{10(g)}+13O_{2(g)}\rightarrow 8CO_{2(g)}+10H_2O_{(g)}$$

$$2-C_4H_{10(g)}+5O_{2(g)}\rightarrow 5H_2O_{(g)}+2CO_{2(g)}+CO_{(g)}+C_{(s)}$$

$$3-2Cu_2S_{(s)}+3O_{2(g)}\rightarrow 2Cu_2O_{(s)}+2SO_{2(g)}$$

$$4-H_2SO_{4(aq)}+CaCO_{3(s)}\rightarrow CaSO_{4(aq)}+H_2O_{(l)}+CO_{2(g)}$$

$$5-4NO_{2(g)}+2H_2O_{(g)}+O_{2(g)}\rightarrow 4HNO_{3(aq)}$$

Questions

1- Choose the correct answer

1- …………. are from primary pollutants of air
A- Acid rain   B- carbon dioxide   C- smog   D- ozone gas

2- ……. … is from gases which cause global warming.
A- Methane   B- Carbon dioxide   C- Nitrogen oxide   D- Ozone

3- ……… is from secondary pollutants of air.
A- Carbon dioxide   B- Sulphur monoxide   C- Nitric oxide   D- Smog

2- Write chemical equations which describe

1- The combustion of butane forming carbon dioxide gas
2- The combustion of butane forming carbon monoxide gas.
3- The reaction of copper I sulfide (C_2S) with oxygen
4- The reaction of sulphuric acid with calcium carbonate.
5- The reaction of nitric oxide with water and oxygen

4- Correct the underlines words

1- Environment pollutants are classified according to their dangers into water, air and soil pollutants.

2- Smog causes the corrosion of interfaces of buildings, metals and fall of trees leaves.

3- Water pollution is caused by many substances, for example carbon dioxide gas

4- We can classify the pollutants of soil into primary and secondary pollutants

5- Smog is from the primary pollutants of air

6- Green house effect causes the occurrence of acid rains phenomenon

7- Acid rains led to the melting of earth poles ice.

4- Write the scientific term

1- Everything around human including physical effects, chemical effects and social effects which affect human's health and social activity.

2- Quantitative and qualitative changes in the living and non living components of environment as a result of human's different activities which disorder ecosystems.

3- They are pollutants which pollute air directly.

4- They are pollutants resulted from the reaction of primary pollutants or other substances together.

5- The gradual increase of temperature of the lower layer of atmosphere which is near to earth surface.

6- A modern branch of chemistry which aims to protect the environment by decreasing the emissions resulted from chemical industry as possible

7- It appears due to the combustion of fuel in cars and transport means, which produces carbon dioxide gas and water vapour.

8- Effect which happens due to the emission of different gases fro pollution sources, which makes the atmosphere acts like a greenhouse.

5- What happens when

1- The decay of ozone layer

2- The increase of the temp. of earth because of global warming.

3- The exposure a mixture of many gases (nitric oxide, ozone, hydrocarbons, oxygen) to sunlight.

4- The increase of the ratio of ozone gas near earth's surface

5- The intervention of human in modifying and spoiling of environmental balance.

Solutions

1- Choose the correct answer

1- carbon dioxide *2- Carbon dioxide* *3- smog*

2- Write the chemical equations

$$1-2C_4H_{10(g)}+13O_{2(g)}\rightarrow 8CO_{2(g)}+10H_2O_{(g)}$$

$$2-C_4H_{10(g)}+5O_{2(g)}\rightarrow 5H_2O_{(g)}+2CO_{2(g)}+CO_{(g)}+C_{(s)}$$

$$3-2Cu_2S_{(s)}+3O_{2(g)}\rightarrow 2Cu_2O_{(s)}+2SO_{2(g)}$$

$$4-H_2SO_{4(aq)}+CaCO_{3(s)}\rightarrow CaSO_{4(aq)}+H_2O_{(l)}+CO_{2(g)}$$

$$5-4NO_{2(g)}+2H_2O_{(g)}+O_{2(g)}\rightarrow 4HNO_{3(aq)}$$

3- correct

1- Their places 2- Acid rains 3- Mercury 4- Air 5- Sulphur oxide
6- Global warming 7- Global warming.

4- Write the scientific term

1- Environment 2- Pollution 3- Primary pollutants 4- Secondary pollutants
5- Global warming 6- Green chemistry 7- Smog 8- Greenhouse effect

5- What happens when

1- Harmful ultraviolet rays will penetrate the atmosphere and reach us, which may cause skin cancer and cataract to humans and harm living organisms

2- This would cause:-
- Melting of ice which causes the increase of sea level, drowning of islands and coastal cities, and the increase of floods.

- The occurrence of drought and desertification of huge areas of earth

- The extinction of many living organisms

- The occurrence of natural disasters

- Loss of number of crops

- Increase of forest fires

3- They will react with sunlight forming smoky fogs (smogs) which stay suspended in the air and envelopes the atmosphere of city

4- This will harm living organisms because of it toxicity and damage plants and different substances (Rubber, industrial threads…etc)

5- This will cause pollution which harms the environment and living organisms

Lesson (2) Reducing pollution



→ *Water is the secret of life on earth because of its unique chemical and physical properties. A lot of organic and inorganic substances can dissolve in water.*

→ *Some particles cannot dissolve in water and stay suspended in it. So, we need to purify and treat water before using it.*

Water treatment

Importance of water treatment

→ *Water treatment works on getting rid of pollutants in water to get pure water which can be used in personal consumption.*

Examples of substances removed from water:-

Bacteria – Viruses – Algae – Metals such as iron, manganese and Sulphur – human pollutants

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Water treatment describes the processes carried out to make water acceptable for a desired use. Generally, the main purpose of water treatment is decreasing or removing any suspensions or pollutants in water.

The main steps of water treatment

- Purification and aeration processes:-

→ *Water passes through a filtration device to get rid of big suspensions*

→ *Water is exposed to air which circulate through it to get rid of any dissolved gases in water*

- Coagulation process:-

→ *Water flows to water treatment laboratory*

→ *Different chemical substances (Ex. Aluminium sulphate – calcium hydroxide) are added to water (some of them are coagulants)*

→ *The previous reaction forms insoluble gelatinous substances, which are calcium carbonates and aluminium hydroxide.*

$$Al_2(SO_4)_{3(aq)} + 3Ca(OH)_{2(aq)} \rightarrow 2Al(OH)_{3(s)} + 3CaSO_{4(s)}$$

→ *Suspensions stick to the previous insoluble gelatinous substances and precipitate at the bottom of precipitation vessel.*

- Clarification (sedimentation) process:-

→ *Water is left in a basin so that the substances resulted from coagulation process precipitates.*

- Filtration process:-

→ *It removes suspensions from water.*

→ *Filtration process is carried out through layers of sand or sand an coal, which remove suspensions resulted from precipitation process.*

- Disinfection (Chlorination) process:-

→ *Chlorine gas or substances which contain chlorine (Ex. Sodium hypochlorite – Calcium hypochlorite) are used to sterilize water because they kill bacteria, microbes and microorganisms. This process is called "Chlorination"*

→ *Other methods can be used to sterilize water instead of chlorine (Ex. Ozone, bromine, iodine, ultraviolet rays), but they are more expensive.*

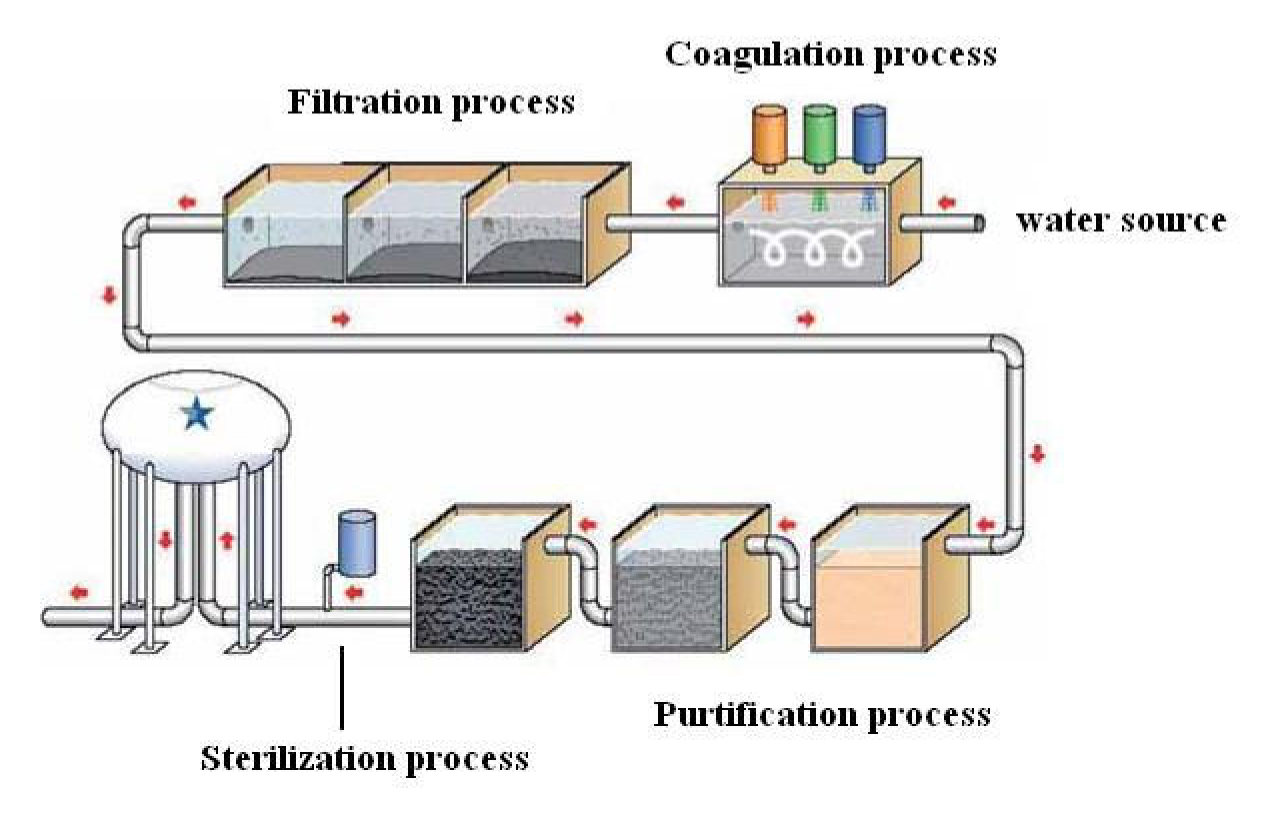


Fig. (12) Water treatment stages

→ *Water treatment methods differ according to water source and the purpose of using it.*

→ *Water may do not need any treatment (Ex. Underground water)*

→ *Water may need certain series of stages of typical or specialized treatment (Ex. Surface water – Underground water which contain high ratio of salts)*



Wastes: *Substances which human stops using and wants to get rid of*

Classification of wastes

Wastes can be classified according to their danger into:-

Non dangerous wastes: *Wastes which don't cause dangerous environmental problems and we can get rid of them by an environmentally-safe method.*

Dangerous wastes: *Wastes which are dangerous to human and living organisms because they may be flammable, potentially explosive, cause corrosion, poisonous or react quickly with nuclear wastes and other substances.*

→ Wastes may be solid (Ex. Rubbish, living organisms wastes), liquid (sewage water), or gaseous (nitrogen, Sulphur and carbon oxides)

Waste treatment

First: Liquid wastes

Sewage water should be treated before being thrown in seas and rives in order to reduce the pollution it causes.

Sources of sewage water

→ They have many sources, sewage water is usually composed of liquid organic substances (From kitchens and bathrooms), which we get rid of through sewage pipes. So, sewage water should be treated.

Sewage treatment: *Purification of sewage water from suspensions, pollutants and organic compounds to make them valid to be reused or to be thrown in water without polluting them.*

→ In countries which lack freshwater, sewage water is being treated in order to be used in agriculture and other purposes.

→ Sewage water treatment has different stages:-

(A) Primary treatment

→ The first stage of sewage treatment

→ It improves the specifications of sewage water by decreasing the amount of pollutants in it; which increases the efficiency of treatment in the following stages.

→ Primary treatment is carried out through mechanical clarifiers which:-
- *Separate floating substances (Ex. Plastic pieces – wood)*
- *Separate sand and surface suspensions (Ex. Fats)*

(B) Secondary treatment

→ *It is the basic stage of sewage treatment*

→ *It provides a suitable climate for the reproduction of microorganisms and bacteria by aeration process.*

→ *Those bacteria and microorganisms change organic and foamy wastes into inorganic substances whose densities are greater than that of water.*

→ *Those inorganic substances may precipitate in gases which leak to the air, or at the bottom of vessel.*

→ *Secondary treatment stage is carried out by two stages:* ***Aeration and mixing – Precipitation basins.***

(C) Advanced treatment

→ *This stage is carried out if we need very pure water*

→ *This stage has many processes which remove substances which cannot be removed in primary treatment (Ex. Nitrogen – phosphorus – organic substances – additional solid suspensions – poisonous substances – dissolved substances).*

(D) Disinfection process

→ *Disinfection process is carried out by injecting chlorine solution to disinfection basin, in a basin called "**contact sewage**"*

→ *The previous process is called "**Chlorination process**"*

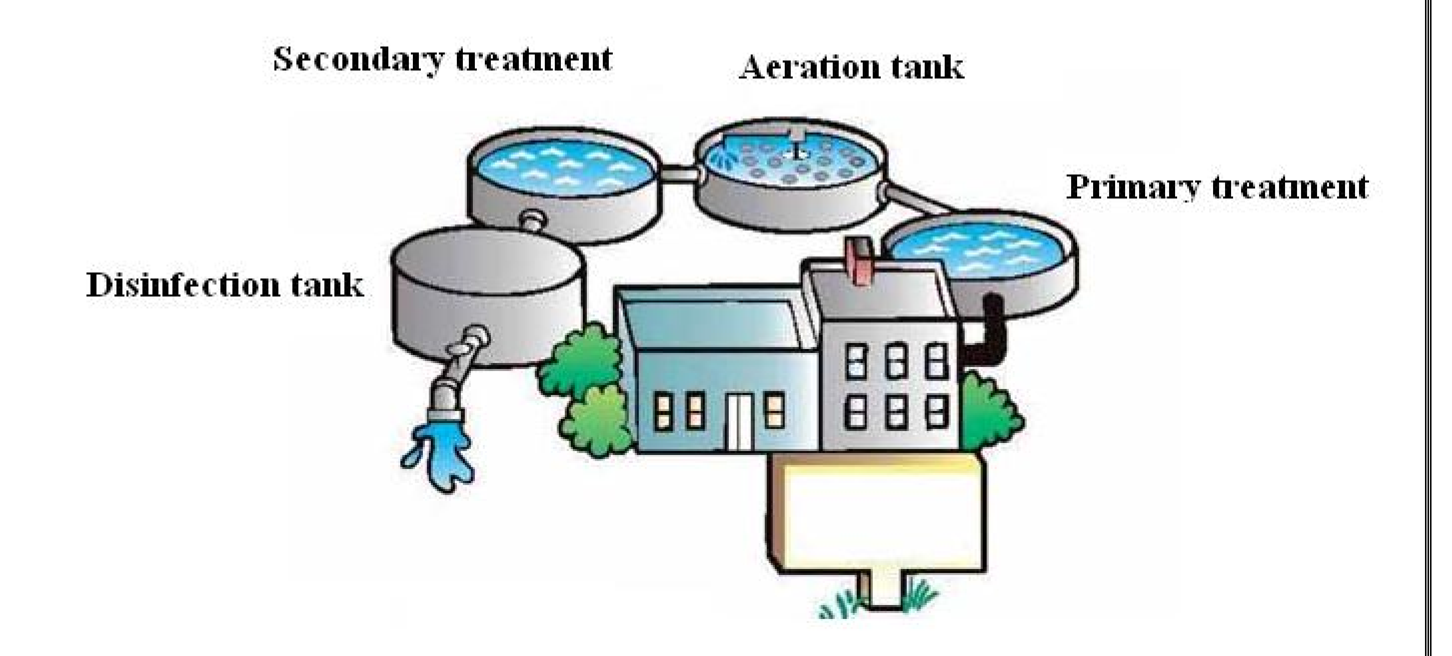


Fig. (13) Sewage water treatment

<u>Uses of treated sewage water</u>

- It is used in agricultural, industrial and other purposes

Second: Solid wastes

→ *They are treated by many methods, which differ according to the components and nature of wastes.*

(A) Reuse

→ *It means using the same product for the same purpose of different ones without being remanufactured*

→ *Reuse is better than remanufacture because it use the same product without being remanufactured, which economize the consumption of additional energy.*

(B) Recycling

Recycling process: *Treatment and remanufacture of wastes by restoring them to their life cycles, which make them valid to be used for the same purpose or different ones.*

→ *Human created the idea of recycling due to the lack of basic substances and human's need for them.*

→ *Recycling process is carried out by classifying and separating wastes according to the raw materials in them, and then manufacturing each material separately.*

Economic importance of recycling

1- Reduce the consumption of primary raw materials
2- Reducing expenditures
3- Protecting environment from pollution
4- Rationalization of electricity consumption.

Recycling of paper

1- Used papers are collected

2- Used papers are soaked in water basin. Then, detergents are added to remove suspensions.

3- The mixture is put in special dough machine. Then, aluminium impurities and mixture of pulp are added to it, and stirring continues until a homogenous dough is formed

4- The homogenous dough flows gradually through a vessel connected to the machine forming carton layers. Then, they are dried.

5- Produced paper are sold

Glass recycling

1- Glass is collected from different sources.

2-Purification of glass by removing impurities and any additions from it.

3- Glass is transported to recycling factory.

4- We add sand, limestone, dolomite (mixture of magnesium and calcium carbonates), soda ashes and other substances to glass to improve the degree of purity

5- That mixture is put in glass melting oven. Then, they are shaped

6- All the products pass through a cooling oven after shaping.

Recycling of plastic

*1- **Sorting:** The first stage of recycling plastic in which plastic loses its properties in case there are other impurities.*

*2- **Washing:** Plastic is washed using caustic soda, or concentrated washing soap added to water. Which makes plastic empty of fats, oils and strange bodies.*

*3- **Transport***

*4- **Breaking (Shredding):** Solid plastic is being broken in breaking machine. Then, plastic is put in beading machine, which cuts it into small beads; in order to become "raw material" which can be used in different industries.*

*5- **Shaping:** Plastic is shaped into different shapes.*

Sustainable development

***Sustainable development:** The development of the earth, cities, societies and commercial works provided that they satisfy the needs of the present, without affecting those of the following generations.*

→ Sustainable development has three aims, which are :-

1- Economic growth

2- Perseverance of environmental and natural resources

3- Social development

Fields of sustainable development

Water:-

- It secures an enough supply of water.

- Increasing the efficiency of using water

- Securing obtaining water

Food

Economic sustainability of food aims to increase the agricultural productivity and production in order to achieve alimentary and export security.

Health:-

Economic sustainability of health aims to increase productivity by:-
1- Preventive and health care
2- Improving health and safety at work places.

Services and home:-

Aims to secure the enough supply and use of building resources and transport means.

The relation between sustainable development and environmental pollution

→ Development depends on the resources of the environment, and development cannot take place without environmental resources.

→ Damage, decrease and pollution of environmental resources affects development. Therefore, we should take environment in consideration to achieve sustainable development.

The end of lesson (2)

Definitions of lesson (2)

Wastes: *Substances which human stops using and wants to get rid.*

Sewage treatment: *Purification of sewage water from suspensions, pollutants and organic compounds to make them valid to be reused or to be thrown in water without polluting them.*

Reuse: *using the same product for the same purpose of different ones without being remanufacture.*

Recycling process: *Treatment and remanufacture of wastes by restoring them to their life cycles, which make them valid to be used for the same purpose or different one*

Sustainable development: *The development of the earth, cities, societies and commercial works provided that they satisfy the needs of the present, without affecting those of the following generations*

Give reasons for

1- Water passes through huge filtration devices during purification process.
To get rid of big suspensions.

2- In coagulation process in water treatment, aluminium carbonate and calcium hydroxide are added to water.
Because they both react with each other forming aluminium carbonates and calcium hydroxide, which are insoluble gelatinous substances. Then, suspensions in water stick to those gelatinous substances.

3- In aeration process of water treatment, water is to air current circulating through it.
To get rid of dissolved gases in water

4- In clarification process, water is left in a big basin
So that the substances resulted from coagulation process precipitate at the bottom of it.

5- The importance of chlorination process in water treatment
Because we add chlorine to water in order to kill any bacteria, microorganisms or microbes in it.

6- Water treatment steps depend on the source of water
Because sometimes water doesn't need to be treated (Ex. Underground water), in some cases, we need certain series of typical or specialized water treatment

stages in order to get pure water (Ex. Surface water and highly-salted underground water)

7- Sewage water should be treated before throwing it in seas and rivers
In order to reduce the pollution caused by it

8- Sewage water has many sources
Because sewage water is usually composed of liquid organic substances. We get rid of sewage water from bathrooms and kitchen through sewage pipes.

9- "Primary treatment" stage is very important is sewage treatment process
Because this stage improves the specification of sewage water by decreasing the amount of pollutants in it.

10- Secondary treatment stage is called the basic stage of sewage treatment
Because it provides a suitable climate for the reproduction of bacteria and microorganisms by aeration process, which change organic wastes to inorganic substances (which we can get rid of easily)
11- Treated sewage water can be used in different purposes
Because it can be used in agricultural, industrial and other purposes.

12- Reuse process is better than remanufacture
Because we use the same product without being remanufactured, which economizes the consumption of additional energy.

13- The importance of recycling process
Because it helps in reducing the consumption of raw materials and expenditures, protecting environment from pollution and rationalization or electricity consumption.

14- There are different methods to treat solid wastes
Because they can be reused in different purposes or the same one without being remanufactures, and they also can be recycled and restored to their life cycles again.

15- Sustainable development plays an important role in water.
Because it helps us secure enough supply of water, increase the efficiency of water use.

16- Sustainable development solve nutrition problems
Because it aims to increase the agriculture productivity and production of food in order to achieve alimentary and export security.

17- Sustainable development plays an important role in health field

Because it aims to increase productivity by health and preventive care, and improving health and safety at work places.

18- Sustainable development is affected by environmental pollution
Because environmental pollution causes the decrease and damage of resources, which have bad effects on sustainable development.

19- Getting rid of wastes by landfill method is not preferred to be used
Because such a method may cause the pollution of water, air and soil.

Questions

1- Choose the correct answer

1- The right arrangement of water treatment stages is……….

A- Chlorination – Filtration – Sedimentation – Coagulation
B- Filtration – Coagulation – Chlorination – Sedimentation
C- Coagulation – Sedimentation – Filtration – Chlorination
D- Sedimentation – Coagulation – Chlorination – Filtration

2- The process in which suspended particles in water are collected at the bottom of vessel is called ……

A- Sedimentation
B- Filtration
C- Chlorination
D- Coagulation

3- The main purpose of chlorination process is….

A- Separating suspension from water
B- Killing microbes
C- Precipitation of particles suspended in water
D- Collecting small particles suspended in water

4- Aluminium sulphate is added to water in ……… process

A- Sedimentation
B- Filtration
C- Coagulation
D- Chlorination

5- Substances floating on sewage water are removed in which stages of sewage treatment.

A- Primary treatment
B- Secondary treatment
C- Advanced treatment
D- Disinfection

6- Most common purposes in which treated sewage water is used is ………

A- Industrial purposes
B- Agricultural purposes
C- Domestic purposes
D- Other purposes

2- Write the scientific term

1- Substances which human stops using and wants to get rid.

2- Purification of sewage water from suspensions, pollutants and organic compounds to make them valid to be reused or to be thrown in water without polluting them.

3- using the same product for the same purpose of different ones without being remanufacture.

4- Treatment and remanufacture of wastes by restoring them to their life cycles, which make them valid to be used for the same purpose or different one

5- The development of the earth, cities, societies and commercial works provided that they satisfy the needs of the present, without affecting those of the following generations

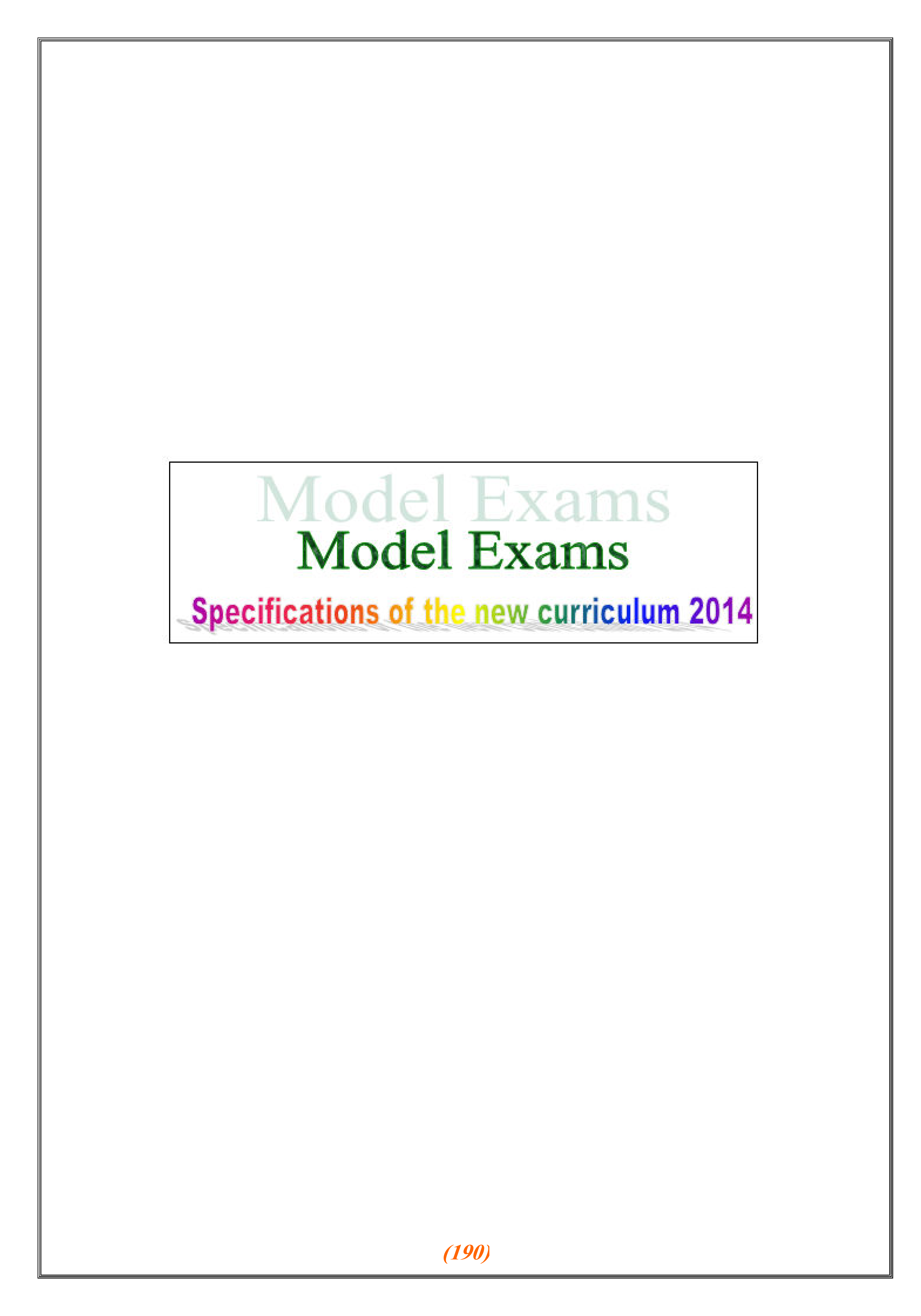


1- Choose the correct answer

1- Coagulation – Sedimentation – Filtration – Chlorination
2- Sedimentation
3- Killing microbes
4- Coagulation
5- Primary treatment
6- Agricultural purposes

2- Write the scientific term

1- Wastes
2- Sewage water treatment
3- Reuse method
4- Recycling
5- Sustainable development


Model Exams
Specifications of the new curriculum 2014

Model Exam (1)

Answer four questions only

Question (1)

1- Choose the correct answer

1- In acidic medium, the colour of methyl orange is ....
A- Yellow B- Red C- Orange D- Green

2- From the tools used to measure the volumes of liquids accurately....
A- Flask B- Pipette C- Burette D- Graduated cylinder

3- Strangeness number (S) of up quark equals.....
A- zero B- 1/3 C- 2/3 D- -1

2- Give scientific reasons for

1- Molar mass of solid sulphur is different from that of gaseous sulphur.
2- Neutrons are used as nuclear projectiles in fission reactions

Question (2)

1- Write the scientific term

1- Substances whose dimensions range from 1 nm to 100 nm.

2- Any qualitative or quantitative change in the components of environment due to human's activities, which cause the disorder of environment balance.

3- Time in which the number of nuclei in a radioactive element falls to half the real value.

2- Find the molecular formula of an organic compound whose molar mass equals 70 g which contains 85.7% carbon and 14.3% hydrogen.

[C=12 , H=1]

Question (3)

1- Correct the underlined words

1- Acid according to Arrhenius is the substance that dissolves in water giving OH^-
2- Smog causes the corrosion of buildings and metals.
3- Substance which is formed when the base gains an electron is conjugate base

2- How does entropy change in the following:-

1- Melting of solid in liquid
2- Change of vapour to solid
3- Liquid freezing

<u>Question (4)</u>

1- Calculate the molar concentration of a solution formed from the dissolution of 42 g of potassium hydroxide in water, and water was added to solution until its volume became 500 ml.

[K = 39, O = 16, H=1]

2- Calculate the change in heat content resulted from the dissolution of 80g of NaOH in an amount of water forming 1 liter of NaOH solution. The initial temperature of water was 20◦C and became 24◦C after dissolution process. Then find:-

- If the reaction is endothermic or exothermic

- Molar heat of solution

<u>Question (5)</u>

1- Mention the economic importance of recycling process and talk about the steps of paper recycling

2- Compare between the definitions of acids and bases according to: Arrhenius – Bronsted and Lowry – Gilbert Lewis

3- Calculate the molar mass and volume of gaseous phosphorus in (STP) conditions.

[P = 31]

Model Exam (2)

Answer four questions only

Question (1)

1- Choose the correct answer

1- The number of molecules in 88g of CO_2

A- $6.02x10^{23}$ B- 4 C- $12.04x10^{23}$ D- 2

2- The symbol of one of the following particles is ${}_{2}^{4}He$

A- Alpha particle B- Beta particle C- Proton D- Neutron

3- pH of an alkaline solution…..

A- 2 B- 5 C-7 D- 8

2- Give scientific reasons for

1- The number of molecules in 9g of H_2O is equal to that of 39g of C_6H_6

[O= 16, C=12, H=1]

2- Nanometer is a unique measuring unit.

3- Different substances have different heat content

Question (2)

1- Write the scientific term

1- Branch of chemistry which studies the protection of environment from pollution by decreasing the emissions resulted from chemical industries.

2- The volumes of reactant and products gases have constant ratios.

3- Heat content resulted from forming one mole of a substance from its elements in STP conditions.

2- If the difference between the total mass of particles forming ${}_{26}^{56}Fe$ nucleus and the mass of its cohesive nucleus equals 0.5u.
Calculate the nuclear binding energy of iron-56 nucleus

Question (3)

1- Correct the underline words

1- Citric acid is from monobasic acids

2- Smog is from primary pollutants of air

3- Volumetric flask is used to measure the mass of matter

2- 39.4g of solid potassium sulphate $BaSO_4$ precipitated when 40g of barium chloride solution $BaCl_2$ reacted freely with potassium sulphate solution (KSO_4)

Calculate the percentage of actual (practical) yield.

[Ba = 137, Cl = 35.5 , S=32]

<u>Question (4)</u>

1- Radium-220 nucleus $^{220}_{88}Ra$ decays giving alpha particle, write the balanced nuclear equation of this reaction

2- If the atoms in 0.12g of carbon were arranged in the form of a line, and the diameter of a carbon atom equals 0.7 nm.
Calculate the length of this line in meters

<u>Question (5)</u>

1- Mentions the harms of:-

A- Nuclear radiation B- Nanotechnology C- Global warming phenomenon

2- Anti-proton is composed of anti-quarks $\{\bar{u}, \bar{u}, \bar{d}\}$, find the values of S,B,Q

3- Calculate the number of sodium ions resulted from the dissolution of 40g of sodium chloride NaCl in water

[Na = 23 , Cl = 35.5]

Model Exam (3)

Answer four questions only

Question (1)

1- Choose the correct answer

1- From two-dimensional nanomaterials

A- Carbon tubes B- Bucky ball C- Nanofibres D- Nanoshell

2- Electron is …………..

A- Lepton B- Hadron C- Baryon D- Quark

3- Randomness degree of a system is ……..

A- Free energy B- Entropy C- Heat content D- Heat capacity

2- Give scientific reasons for

1- When a nucleus emits gamma rays, neither its mass number or its atomic number changes.

2- Landfill method is not preferred to get rid of wastes

Question (2)

1- Write the scientific term

1- The mass of atom or molecule described in grams

2- The quantity of heat required to increase the temp. of a body through 1◦C

3- The number of moles dissolved in one liter of solution

2- In the following nuclear reaction $^{4}_{2}He + ^{14}_{7}N \rightarrow ^{17}_{8}O + ^{1}_{1}H$ **:-**

The sum of masses of reactant nuclei = 18.0114 u

The sum of masses of product nuclei = 18.0126 u

Kinetic energy of alpha particle = 0.0083 u

→Calculate the kinetic energy of product nuclei in (u)

Question (3)

1- Compare between:-

A- Exothermic and endothermic reactions

B- Alpha and beta particles (Charge – Penetration ability – Ability to ionize air)

2- Calculate the volume of hydrogen gas in (STP) resulted from the reaction of 23g with water.

$$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$$

Then, find the number of sodium ions resulted from this reaction

Question (4)

1- Write the balanced ionic equation of the following reaction: *Adding sodium chloride solution to silver nitrate solution forming sodium nitrate and white ppt. of sodium chloride*

2- Calculate the no. of alpha particles resulted from the decay of thorium $^{228}_{90}Th$ ***to polonium*** $^{216}_{84}Po$

3- Mention one application of nanotechnology in each of the following fields:-

A- Agriculture

B- Medicine

C- Industry

Question (5)

1- Write the scientific term

1- Glass tool with certain volume fixed vertically and used in titration process.

2- Science which deals with the manipulation of matter on nanoscale to get unique products.

3- Using the same product in the same or different purposes without being remanufactured.

2- (X) is the nucleus of a radioactive element, when it emitted 5 alpha particles and 4 beta particles, it turned into the nucleus of element $^{206}_{80}X$

Find the nuclear symbol of nucleus (X)

Model Exam (4)

Answer four questions only

Question (1)

1- Choose the correct answer

1- One nanometer equals .... Meter

A- 10^{-9} B- 10^{-7} C- 10^{3} D- 10^{-1}

2- When NH_3 reacts with HCl, NH_4^+ is ......

A- Conjuagte base B- Conjugate acid C- Acid D- Base

3- The volume of H_2 required to form 11.2L of water is ....

A- 11.2 B- 22.4 C- 44.8 D- 89.6

2- What is meant by:-

A- Biochemistry

B- Ionizing radiation

3- Describe the following by balanced equations

1- Coagulation process

2- ${}^{226}_{88}Ra$ undergoing alpha decay.

Question (2)

1- Write the scientific term

1- A formula which describe the simplest ratio between the atoms forming compound.

2- The heat of reaction has a constant value that doesn't change, even if the reaction occurred in more than one step.

3- Weak acid or base whose colour change by the change of pH of solution

Question (3)

1- How to differentiate between:-

A- Litmus solution - Phenolphthalein

B- True solution – Colloidal solution

2- Mention three of the principles of green chemistry

Question (4)

1- Within 12 minutes, 75% of the nuclei of a pure sample of a radioactive element decayed.
Find the half- life of that radioactive element.

2-Calculate the heat of the following reactions, and find if it its exothermic or endothermic.

$$CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{(g)}$$

(O=O) 498, (C-H) 413, (O-H) 467, (C = O) 745

Question (5)

1- Choose the correct answer

1- If O = 16, H=1, number of moles in 36 g of water equals……
A- 0.5 B- 1 C- 2 D- 3

2- $^{4}_{2}He + ^{9}_{4}Be \rightarrow ^{12}_{6}C + X$ *, (X) represents …….*
A- e^- *B- n C- p D- γ*

3- Molality of a solution is measured by
A- mol/L B- g/eq.L C- g/L D- mol/Kg

2- Give scientific reasons for

1- Boiling point of a solution is greater than that of pure water
2- The gradual increase of the temp. of lower layer of atmosphere.

Model Exams Answers

Model Exam (1)

Question (1)

1- Choose the correct answer

1- Red
2- Burette
3- -1

2- Give reasons for:-

1- Because a molecule of gaseous sulphur contains 8 atoms of sulphur, while that of solid sulphur contains only 1 atom.

2- Because they are perfect projectiles, as they can enter nuclei without being repulsed because they are neutral.

Question (2)

1- Write the scientific term

1- Nanomaterials
2- Pollution
3- Half-life

2-

Hydrogen	:	Carbon
$\frac{14.3}{1}$		$\frac{85.7}{12}$
14.3		7.1416
2		1

The empirical formula: CH_2

The molar mass of the compound = 12 + 1+1+ = 14 gm

The no. of units = 42/14 = 3 units

The molecular formula = $CH_2 \times 3 = C_3H_6$

Question (3)

1- Correct the underlined words

1- H^+
2- Acid rains
3- Conjugate acid

2- How does entropy change in the following:-

1- Increases
2- Decreases
3- Decreases

Question (4)

1-

Molar mass of KOH = 39 + 16 + 1 = 50g
No. of mole in 42g = Mass / molar mass = 42/50 = 0.75 mol.
→ Volume of solution = 500 ml = 0.5 L
→ Molarity = no. of moles / volume = 0.75 / 0.5 = 1.5 Molar (mol/L)

2-

If the density of solution = 1 g/ml
If the volume = 1 liter = 1000 ml

The mass (m) = 1000 g
Specific heat (c) = 4.18
Difference in temp. (ΔT) = 24 – 20 = 4°C

Amount of heat = c x m x ΔT = 4.18 x 1000 x 4 = + 16720 J = 16.72 kJ

→ Dissolution is endothermic because the sign of change in heat content is positive.

Molar mass of sodium hydroxide = 23 + 16 + 1 = 40g
No. of moles in 80g = 80 / 40 = 2 moles

→ Molar heat of solution = heat content (in kJ) / no. of moles = 16.72 / 2 = 8.36 kJ / mol

Question (5)

1-

Importance of recycling:

1- Reduce the consumption of primary raw materials
2- Reducing expenditures
3- Protecting environment from pollution
4- Rationalization of electricity consumption.

Paper recycling:-

1- Used papers are collected

2- Used papers are soaked in water basin. Then, detergents are added to remove suspensions.

3- The mixture is put in special dough machine. Then, aluminium impurities and mixture of pulp are added to it, and stirring continues until a homogenous dough is formed

4- The homogenous dough flows gradually through a vessel connected to the machine forming carton layers. Then, they are dried.

5- Produced paper are sold

	Acid	***Base***
Arrhenius	*- Substance which disassociates in water producing positive hydrogen ions H^+*	*- Substance which disassociates in water producing negative hydroxide ions OH^-*
Bronsted-Lowry	*- Substance which loses proton H^+ during chemical reactions*	*- Substance which gains proton during chemical reactions*
Gilbert Lewis	*- Substance which gains one or more electrons during chemical reactions*	*- Substance which loses one or more electrons during chemical reactions*

3-

A molecule of gaseous phosphorus has 4 atoms

→ Molar mass = 4 x 31 = 124g

→ Volume of gas (in STP) = 22.4 L

Modal Exam (2)

Question (1)

1- Choose the correct answer

1- 12.04×10^{23}

2- Alpha particle

3- 8

2- Give scientific reasons for

1- Because 9g of water contains 0.5 mole of it, while 39g of C_6H_6 contains 0.5 mole of it. According to Avogadro, No. of molecules in a mole of any substance contains a constant number of molecules, atoms or ions ($6.02x10^{23}$)

2- Because substances which have Nano dimensions have unique and extraordinary properties (which are different from bigger substances)

3- Due to the difference in kind and number of atoms, and the way they bind to each other.

Question (2)

1- Write the scientific term

1- Green chemistry

2- Gay-Lussac's law

4- standard heat of formation

2-

Mass defect (Δm) = 0.5 u

→ Nuclear binding energy = 0.5 x 931 = 465.5 MeV

Question (3)

1- Correct the underline words

1- Tribasic

2- Smog

3- Sensitive balance

2-

$$BaCl_2 + K_2SO_4 \rightarrow BaSO_4 + 2KCl$$

Molar mass of $BaCl_2$ = 137 + 35.5 +35.5 = 208g

Molar mass of $BaSO_4$ = 137 + 32 + 4x16 = 233g

One mole of $BaCl_2$ → One mole of $BaSO_4$

208 g of $BaCl_2$ → 233g $BaSO_4$

40 g of $BaCl_2$ → 0.2 mole of $BaSO_4$

Mass of $BaSO_4$ (Theoretically) = (40 x 233) / 208 = 44.8g

Mass of $BaSO_4$ (Practically) = 39.4 g

→ Percentage yield (practical yield percentage) = 100 x (39.4/44.8) = 88%

Question (4)

1- $^{220}_{88}Ra \rightarrow ^{216}_{86}X + ^{4}_{2}He$

2-

Molar mass of carbon = 12g
Moles in 0.12g = 0.01 mol
No. of atoms in 0.01 mole = 0.01 x 6.02×10^{23} *=* 6.02×10^{21} *atoms*
Length of the line = 0.7 nm x 6.02×10^{21} *=* 7×10^{-10} *x* 6.02×10^{21} *=* 4.214×10^{12} *m*

Question (5)

1- Mentions the harms of:-

A- Nuclear radiation:-

It ionizes water molecules in cell, which causes its death, the delay or prevention of cellular division, the continuous division of cell uncontrollably (caner) or the occurrence of mutations

B- Nanotechnology:-

1- Nanoparticles can penetrate the cells of lungs and skin in human, and the cells of plants and animals; which may cause health problems to them.

2- It may worsen the problems of social and economic inequality, and the unfair distribution of technology and wealth.

C- Global warming

1- Melting of ice which causes the increase of sea level, drowning of islands and coastal cities, and the increase of floods.
2- The occurrence of drought and desertification of huge areas of earth
3- The extinction of many living organisms
4- The occurrence of natural disasters
5- Loss of number of crops
6- Increase of forest fires

2-

Anti - Proton $= \{ \ \bar{u} \quad \bar{u} \quad \bar{d} \ \}$

$$Q\ (-1e) = \left(-\frac{2}{3}\right) + \left(-\frac{2}{3}\right) + \left(+\frac{1}{3}\right)$$

$$B\ (-1) = \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right) + \left(-\frac{1}{3}\right)$$

$$S\ (0) = 0 + 0 + 0$$

3-
One mole of sodium hydroxide = 23 + 16 + 1 = 40g
The no. of NaOH moles = 1 mol
The no. of produced sodium ions = 1 x 6.02×10^{23} = 6.02×10^{23} atoms

Model Exam (3)

Question (1)

1- Choose the correct answer

1- Carbon tubes
2- Lepton
3- Entropy

2- Give scientific reasons for

1- Because gamma rays are uncharged because they are electromagnetic waves. Nuclei emit gamma rays in order to get rid of excess energy only.
2- Because dumped wastes may pollute air, water and even soil.

Question (2)

1- Write the scientific term

1- Mole
2- Heat capacity
3- Molarity (molar concentration)

2-

Sum of masses of reactants = 18.0114 + 0.0083 = 18.0197 u
Sum of masses of products = 18.0126 u
Mass defect (ΔM) = 18.0197 – 18.0126 = 0.0071 u
The kinetic energy or products = 0.0071 x 931 = 6.6 MeV

Question (3)

1- Compare between:-

Endothermic reactions	***Exothermic reactions***
- Change in heat content is positive *- They absorb energy*	*- Change in heat content is negative* *- They give off energy.*

	Alpha particle	**Beta particle**
Charge	Positive (+2 e)	Negative (-e)
Penetration ability	Weak – cannot penetrate a sheet of paper	Stronger than alpha – cannot penetrate aluminium sheet of 5 mm thickness
Ionization of air	Strong	Weaker than alpha

2-.

$$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$$

One mole of sodium = 23g
Two moles of sodium → One mole of hydrogen
One mole of sodium → 0.5 mole of hydrogen
The volume of hydrogen gas = no. of moles x 22.4L = 0.5 x 22.4 = 11.2 L

Question (4)

1- $NaCl_{(aq)} + AgNO_{3(s)} \rightarrow NaNO_{3(aq)} + AgCl_{(s)}$

$$Na^+_{(aq)} + Cl^-_{(aq)} + Ag^+_{(aq)} + NO_3^- \rightarrow Na^+_{(aq)} + NO_3^- + AgCl_{(s)}$$

→ Sodium and nitrate ions are omitted from both sides because they do not react with any other ions. As sodium nitrates on right hand side is an aqueous solution (aq)

$$Cl^-_{(aq)} + Ag^+_{(aq)} \rightarrow AgCl_{(aq)}$$

2-
Difference between mass no. of thorium and polonium = 228 – 216 = 12
Mass no. of an alpha particle = 4
No. of alpha particles = 12 / 4 = 3 particles

3- Mention one application of nanotechnology in each of the following fields:-
A- Agriculture: Food preservation
B- Medicine: Early diagnosis of diseases
C- Industry: Production of stain-repellent clothes with auto-cleaning property

Question (5)

1- Write the scientific term
1- Burette
2- Nanotechnology
3- Reusing

2- $X \rightarrow 5\,{}^{4}_{2}He + 4\,{}^{0}_{-1}e + {}^{206}_{80}X$

Change in atomic number = 5x2 + 4x -1 = 10 – 4 = 6
Change in mass number = 5x4 + 4x0 = 20
The mass number of nucleus (X) = change in mass no. + mass number of ${}^{206}_{80}X$
= 20 + 206 = 226
The atomic number of (X) = change in atomic no. + atomic number of ${}^{206}_{80}X$
= 80+6 = 86

Nuclear symbol of (X) = ${}^{226}_{86}X$

Model Exam (4)

Question (1)

1- Choose the correct answer

1- 10-9

2- Conjuagte base

3- 11.2L

2- What is meant by:-

A- The science which studies the chemical structure of living organisms and the reactions occurring withing them

B- Radiation which ionizes the atoms it hits and changes the structure of tissues it penetrates.

3- Describe the following by balanced equations

1- $Al_2(SO_4)_{3(aq)} + 3Ca(OH)_{2(aq)} \rightarrow 2Al(OH)_{3(s)} + 3CaSO_{4(s)}$

2- ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}X + {}^{4}_{2}He$

Question (2)

1- Write the scientific term

1- Empirical formula

2- Hess's law.

3- Indicator

Question (3)

1- How to differentiate between:-

*A- **Litmus solution**: Acids change its colour to red, while bases change it to blue. Neutral solutions make its colour purple*
***Phenolphthalein**: Acids and neutral solutions make it colourless, while bases change its colour to*

*B- **True solution**: It is a homogenous mixtures whose components cannot be seen by naked eyes and regularly-distributed across all its parts*

***Colloidal solution:** A non homogenous mixture whose components do not precipitate and particles cannot be separated by filter paper*

2- Mention three of the principles of green chemistry

- Achievement of atomic economy principle

- Chemical preparations shouldn't be harmful to environment

- Reduction of creating harmful chemicals

Question (4)

1- After 12 min, 75% of nuclei decayed. Therefore, 25% of nuclei remained.

$$100\% \xrightarrow{\text{period (1)}} 50\% \xrightarrow{\text{Period (2)}} 25\%$$

Time = 12 min.

No. of periods = 2

Half-life = Time / no. of periods = 12 / 2 = 6 min

2-

$$CH_4 + 2\,O{=}O \longrightarrow O{=}C{=}O + 2\,H_2O$$

413 kJ / mol (C–H), 498 kJ / mol (O=O), 745 kJ / mol (C=O), 467 kJ / mol (O–H)

The energy required to break up the reactant molecules =

[4 x (C – H)] + [2 x (O = O)] = [4 x 413] + [2 x 498] = 2648 kJ

The energy released from forming the product molecules =

[2 x (C=O)] + [4 x (O – H)] = [2 x 745] + [4 x 467] = 3358 kJ

$\Delta H = H_{products} - H_{reactants} = 3358 - 2648 = +710$ kJ / mol.

The change in heat content is positive, therefore the reaction is endothermic.

Question (5)

1- Choose the correct answer

1- 2

2- γ

3- Molality of a solution is measured by
A- mol/L   B- g/eq.L   C- g/L   D- mol/Kg

2- Give scientific reasons for
1- because the solute particles in solution decrease the no. of water molecules escaping from the surface of water, which decreases vapour pressure and increases boiling point.

2- Due to the increase of ratios of greenhouse gases in the atmosphere due to the combustion of fuel, overcutting or trees and different human activities, which changes the climate of earth and increases its temperature.